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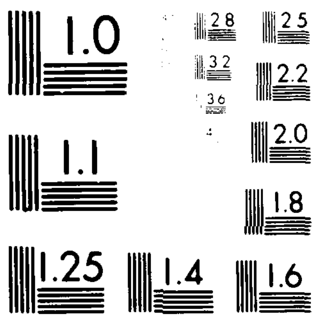

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THESIS

AN EVALUATION OF THE EFFECTIVENESS OF COLOR CODED TACTICAL SYMBOLOGY APPLIED TO MILITARY MAPS

by

Peter Kafurke

September 1981

Thesis Advisor: W. F. Moroney
Co-Advisor: D. E. Neil

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This thesis examined the effect of using color coded tactical symbology on military maps. It reviewed the basic aspects of color coding techniques and described a task paced experiment in which conventional monochrome(blue vs. red) coding techniques were compared to multiple color coding. The multicolor coded stimuli used were 5 standard symbols representing Artillery, Armor, Infantry, Mechanized Infantry and Engineers. The symbols were coded red, green, blue, orange and black respectively. The analysis of the data obtained from 20 subjects revealed that performance under multicolor coding condition was

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An Evaluation of the Effectiveness of Color Coded
Tactical Symbology Applied to Military Maps

by

Peter Kafurke
Captain, Federal German Army
Betriebswirt (Grad.), FHSH 1, Darmstadt, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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NAVAL POSTGRADUATE SCHOOL
September 1981

Author: Peter Kafurke

Approved by: William F. Moroney
Thesis Advisor

[illegible]
Co-Advisor

Kneale T. Marshall
Chairman, Department of Operations Research

W M Woods
Dean of Information and Policy Sciences

ABSTRACT

This thesis examined the effect of using color coded tactical symbology on military maps. It reviewed the basic aspects of color coding techniques and described a task paced experiment in which conventional monochrome (blue vs. red) coding techniques were compared to multiple color coding. The multicolor coded stimuli used were 5 standard symbols representing Artillery, Armor, Infantry, Mechanized Infantry and Engineers. The symbols were coded red, green, blue, orange and black respectively. The analysis of the data obtained from 20 subjects revealed that performance under multicolor coding condition was significantly superior with respect to response time, accuracy of response and accuracy of location transfer onto a copy of the displayed map.

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I. INTRODUCTION

A. PURPOSE

This study examined the color coding techniques as applied to map design. It concentrated on the application of redundant color coding on maps as a means of information transfer and particularly on the differences in response time to locate and recognize symbols presented either monochromatically or as different colors.

Many studies have measured the effectiveness of symbols including the use of colors as a coding dimension. But only a few addressed situations similar to battlefield operation displays. Some studies compared standard military symbols to an alternative set of symbols, because, as Hemingway and Kubala [Ref. 1] state, the symbology currently employed by the army in tactical displays is still less than optimum for present day use. This thesis, however, utilizes the conventional symbols since they are standardized internationally and required by regulations. Changing them would involve inumerable organizational problems.

Hence this thesis will address the application of color as a second coding dimension, applied to military maps as an aid in interpreting the mass of information provided on a considerably congested display. It concentrates on the effect of color coding on maps and particularly on the differences in response time to locate and recognize single colored or multicolor coded symbols.

B. GENERAL ASPECTS OF DISPLAYS

1. Purpose of Displays

In addition to stimuli people can sense directly there are those which cannot be sensed adequately under certain circumstances, because they might be too far, too small or not intense enough. Other stimuli may require reduction, conversion to another form for transmission or more precise measurement in order to enable people to perform certain activities. Under these circumstances the relevant stimuli or information have to be transferred indirectly by a display in either reproduced or coded (symbolic) form [Ref. 2].

Whether a display meets the purpose or not depends on factors such as the perceptual performance (capability) of the operator, performance data of the display and the properties of the information to be displayed. Generally, each display must be optimized and fitted to the specific purpose.

Despite apparent differences, display systems have one essential characteristic in common: the concern with the transfer of information to the human operator or decision-maker. However, the development of more sophisticated display systems have increased the challenge to the human operator for data acquisition. This conflict requires the human engineering specialists to examine man's perceptual capabilities and his intended responses to the given information in order to find the appropriate design for a specific task.

The crucial problem is the detection and definition of those variables which determine the performance of the operator. Those variables include:

- display parameters
- task variables
- operator characteristics and
- the interaction of these elements.

They are essential particularly for the design of military displays, since increased mobility of mechanized units makes frequent updating a necessity, particularly if information is required for commanders on real time basis. Often large numbers of different symbols representing unit types as well as symbols for different functions are presented. This results in congested displays making it hard for the commander to obtain the overall picture in a relatively short period of time.

Hence, rapid and accurate recognition of symbols describing a certain situation is of utmost importance. The common task before acting involves recognition, detection and counting of units in a given terrain as well as the recognition of their deployment relative to each other.

2. Types of Displays

The design of display systems is determined by the kind of information to be presented. Besides quantitative information (e.g., measurements) and qualitative information (e.g., change of variables or parameters) representional and identification information are of special interest, particularly those representing objects or other configurations by pictorial, graphic or symbolic means.

Both quantitative and qualitative information can be presented on dynamic or static displays. Dynamic displays are those which change their information continually over time like gauges and meters, CRT displays as radar, television and radio signal transmitters transferring stimuli in either analogous or digital form.

On the other hand, there are static displays, such as photographs and maps, which remain fixed through time. The dynamic aspect of information display is a consideration when these displays carry additional information subject to changes within certain time periods.

3. Military Requirements on Displays

Rapidly changing battlefield situations on the one hand and the state of the art in display technology on the other hand may lead one to believe that the day of the conventional manually constructed display is over. This is emphasized by the fact that many sophisticated automated display technologies have been developed and deployed. Inspite of these technological developments, at least at the lower level of the hierarchy of command, the conventional map display remains the primary technique for the display of information. In addition, even the higher level of command, where the more sophisticated means are available, cannot relinguish the conventional display in case of jamming or broken data links.

The importance of the use of maps as displays is underlined by the German Army's Field Manual HDV 100/200 Nrs 326-334 [Ref. 3]. It states: "Die Lagekarte ist eine wesentliche Grundlage fuer die Anwendung des Fuehrungsvorganges. Daher sind die Informationen uebersichtlich und eindeutig erkennbar darzustellen."[1]

Irrespective of the type of display used, coding dimensions are determining factors in meeting the requirements of surveyability and

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[1]The situation map is an essential basis for the application of the "command process". Therefore, all informations have to be represented in an easy to survey and unequivocal way.

unequivocal presentations. Those factors will be discussed in the following paragraph.

C. CODING DIMENSIONS

1. General Aspects

In examining the transfer of information, it is important to determine the relationship between the user requirements, i.e., the information to be displayed and the perceptual performance of the user. The observer can be an operator in an information center or commander required to evaluate the situation and making subsequent decisions.

Over the past two decades many parameters for imaging systems have been investigated. Display variables under consideration have included: brightness, contrast, sizes, shades, number of scan lines and resolution which have been compared with viewing variables as distance, scene complexity or clutter, target size and shape, motion, field of view and physical environment [Ref. 4]. But all these variables must be seen in the immediate context of the selected stimulus dimensions which in turn depend on the nature of the situation.

So any generalization of the use of codes are at best context and situation specific. However, there are certain criteria to be considered [Ref. 2]:

- DETECTABILITY - how well the stimulus can be sensed by the sensing mechanism
- DISCRIMINABILITY - the degree of difference between adjacent stimuli
- COMPATIBILITY - referring to the spatial, movement, or conceptual relationship of stimuli and of response (e.g., a red

light is associated with warning and so generally perceived by people).

- MEANINGFULNESS - the code is either actually symbolic of its representation or the meaning can be learned.
- STANDARDIZATION - particularly important in military tactical display systems used by different people.

2. Symbology

In addition to those general factors a matter of interest has been and still is what kind of symbology to use for tactical displays. Symbolic coding makes information available to the user, allowing for improved efficiency and reducing errors [Ref.] 5 .

Particularly when using electronic displays it is important to use symbols which are easily recognizable. Considering the display requirements for presentation of a corps level area it becomes obvious that the number and variety of symbols have a serious impact on recognizability. Hemingway et al. [Ref. 5] quote "...A corps level area terrain analysis requires the generation and control of at least 75 topographic map sheets at the 1:50000 scale along with 814 terrain factor overlays." When this information is overlaid on map backgrounds the result is a congested and hard to interpret mass.

Using symbols only to represent unit types assembled in a small area can result in an extremely cluttered display. To avoid masking and overlapping of symbols on CRT displays, they must be reduced in size so that they become almost illegible, or only small sectors of the display may be examined at a time.

As Hemingway and Kubala [Ref. 1] state, the symbology currently employed by the army is still less than optimum for present day use.

They compared standard military symbols to an alternative set of symbols with respect to response time and accuracy of response. In addition to the use of different symbols they applied a redundant color code (red arrow for artillery, blue square for armor, yellow circle for infantry, and green diamond for mechanized infantry). Since the task was to compare changing battlefield situations from one display to the next, the observed change in response time (which was found to be faster with the experimental symbols) was very likely due to a learning or practice effect.

Another problem in the use or development of adequate symbology is how to maintain the feature of iconic representations to provide association values. This characteristic is generally found in current military symbols, e.g., the propeller for aviation, the bridge for engineers and the crossed sword for infantry.

3. <u>Color as Coding Dimension</u>

The problem of using color in providing specific information for an operator or decision maker has existed for a long time. Color has been studied both as a method of representing realistic or natural imagery and as a means of coding information. Literature indicates that the major part of the work has been concerned with threshold investigations, theoretical concepts with information theory and physiological mechanism linked to color vision [Ref. 4].

Opinions about suitability and advantages of colors as coding dimension are widely spread. The literature reveals that

> "the value of color as coding method is entirely dependent on its effective use in a specific application. That is, it can be beneficial, neutral or distracting. Which of these outcomes will occur is a function of how, where and when it is used. The operator task, the environment, the display medium, and the specific way in which color coding is applied are all important." [Ref 6]

However, there seems to be agreement that color has proven to be the most effective code for a task involving visual search [Ref. 7]. The last point should be given careful consideration. As Cahill et al. Ref 8 reported, the advantage of using color as a code decreases as the number of colors added to a display increases. Actually the search time is highest at the two extremes, that is, the color code is completely redundant with individual item or there is no color code at all. This finding suggests that the use of color should be limited to specific types of tasks.

4. Color Coding and Task Requirements

Since the individual is still the primary analyst of information, easy recognition of symbols on a display must be emphasized. Particularly when visual pattern recognition is involved in decision making, the operator must assign the observed pattern to some template in his memory. So the more information the pattern presents to the operator, the more information he has on which to base his decision. That means, that decision making will be more efficient when the pattern contains both shape and color and hence enhances recognizability. The literature indicates, that both speed and accuracy of interpretation are enhanced when redundant coding is employed. Krebs et al. [Ref. 6] suggests the use of colors on displays.

- when symbols are difficult to see as a redundant dimension to improve symbol visibility and discriminability
- to group spatially separated but related information (e.g., a series of checkpoints on a map or friendly vs. enemy installations)

- to reduce the effective density of items on a cluttered display by separating them into several color categories where the symbols can be assigned to task related groups

and further when

- the display is unformatted
- the symbol density is high
- the operator must search for relevant information
- the color code is logically related to operator's task
- the symbol legibility is degraded.

Similar conclusions have been inferred by Christ [Ref. 9]. He states that human performance is usually improved when color is combined with other coding dimensions, e.g., alphanumeric or geometric shapes, with either total or partial redundancy. One main advantage appeared to be that color provided an additional dimension for the presentation of information without requiring extensive additional training.

Hitt [Ref. 7] showed that color was significantly superior for the location task, poorest for identification, second for counting, comparing or verifying the existence of certain target symbols. An increase in the number of code levels and target density degraded operator performance in all code types.

5. Number of Colors to be Used

The number of colors, or hues, distinguishable by the human eye varies considerably. The range has been documented from an astonishing 350,000 just noticeable differences [Ref. 10] to a more modest 180 normal segments of the spectrum [Ref. 11]. It is generally agreed that the number of distinguishable segments is highly dependent upon a number

of factors including the environment, the task, and the accuracy of measurement desired. Realistically, in the operational environment, the number of different least confusable colors for normal observers has been suggested to be between six and nine [Ref. 12].

Cook [Ref. 13] generalizes that even on denser displays the usage of multiple colors does not appear to produce any "confusion penalty". Using up to five colors has no adverse effect on search time as long as the observer knows which color he is searching for. Krebs et al. Ref. 6 suggested that the number of colors should not exceed four when identification is required even though up to 50 colors may be identified with extensive training. Saenz et al. [Ref. 14] investigated four colors, four geometric shapes, and four redundant color-shape coded targets on a background containing clutter objects consisting of irrelevant shapes and colors and found the redundant code to be more effective with respect to search times.

6. Determinants for Choosing Color

Krebs et al. [Ref. 6] listed basic criteria for color selection as follows:

- maximum wavelength separation
- high color contrast
- high visibility in specific application
- compatibility of use with conventional meaning
- legibility and ease of reading
- high saturation

The generalized criterion to use in selecting a set of colors is to choose colors as widely spaced in wavelength as possible along

the visible spectrum. Krebs et al. [Ref. 6] specified 10 colors which, under good viewing conditions, can be identified correctly nearly 100 percent of the time.

Table 1
Identifiable Colors Selected for Maximum Wavelength Separability

Dominant Wavelength (nm)	Color Name
430	violet
476	blue
494	greenish-blue
504	bluish-green
515	green
556	yellow-green
582	yellow
596	orange
610	orange-red
642	red

Cook [Ref. 13] in a review of the color coding literature suggested the use of six common colors: purple, blue, green, yellow, orange, red and concluded that multicolor displays are advantageous in terms of faster response time or fewer errors or both. This supports the position that the same advantages can be yielded by adequate application to maps. However, special conditions such as type of display, background (noise) and operator task will determine the actual number of useful colors. So

it is particularly important to choose colors of high contrast (e.g., the relationship between the luminance of a symbol and its background), in connection with saturation as an additional color dimension when applied on maps. Saturation refers to the purity of color and is that aspect that is most strongly influenced by the addition of white light [Ref. 15]. Saturation differences are used, for instance, to produce the color variations on maps and is especially important where the maximum number of colors is being used as a coding mechanism.

7. Summary

The parameters to be considered in developing a color code to be applied on tactical displays and particularly on maps include: the number of colors in the code (code size), hue, task requirements, symbology, contrast, saturation, display background, density and interaction between density and code size. The significance of maps as a display background will be discussed in the next section.

D. INFORMATION PRESENTATION ON MAPS

1. Purpose of Maps

The tactical employment of ground forces is highly affected by the terrain; therefore, knowledge about the terrain is essential. Terrain determines cover and concealment, fire effectiveness, avenues of approach for both enemy and own troops, general cross country trafficability and hence the possibilities of movements and surprise. Hence military commanders rely on maps in their evaluation of any battlefield situation. The U.S. Army's Field Manual FM 21-26 [Ref. 16] defines a map as follows: "A topographic map is a mathematically determined presentation of a portion of the earth's surface systematically plotted to

scale upon a plane surface." So maps are essential to the provision of comprehensive information on the existence and location of ground features as well as on the distances between them. They indicate variations in land forms and heights of natural features. Hooper [Ref. 17] stated, maps

> "...are not the enviroments themselves but are, instead, displays designed to present an environment in its absence...in such a way as to allow the map reader systematically to derive attributes of the mapped enviroment...the primary intent of a map is to convey enough information about an environment to a user so that he...can understand an environment well enough to plan actions within it."

The type of a map to be used is generally dictated by the purpose. Military operators require certain features to provide the necessary information about the terrain and link them immediately to the most important matter of interest: the optimal deployment of ground troops. Information concerning terrain and military units, notably those of the enemy provide the basis for evaluation of the situation and subsequent decisions.

However, the concept of a map is media and symbology independent. Generally speaking the media selected is determined by the appropriateness and availability, as for instance paper printed maps or computer generated CRT-displays. The map as a mean of information presentation typically contains topographic and geographic information. The individual as the analyst, however, has control in examining a map. It is up to him to ignore certain elements or to emphasize portions of the map according to the given need and situation [Ref. 17]. Actually the basic and typical information of a map can be just "background noise" for the operator whose immediate concern it is to detect and identify certain units in as short a time as possible.

2. Categories of Military Maps

The technology of map making and optimum use of mapping techniques provides purpose tailored maps for all kinds of military applications. The general distinction is made with respect to type and density (resolution) of information. Of all the different types of maps (e.g., photomaps, plastic relief maps, planimetric maps) the topographic map generally is the most used "all purpose" map. It shows terrain and land forms in a measurable form. The vertical positions (relief) are presented by contours, shading and color coding. In addition to these types of maps are many maps for special purposes available as for vegetation, climate, roads and bridges, surface water resources, just to mention a few.

Another categorizing factor is the scale of a map, e.g., the relationship between distance on a map and distance on the ground expressed as a fraction or ratio [Ref. 18]. Hence, the larger the number after the 1 (e.g., 1:50,000), the smaller the scale of the map. According to Field Manual FM 21-26 [Ref. 16], small scale maps at scales of 1:600,000 to about 1:100,000 are commonly used for strategical planning at the higher levels of command. Medium scale maps between 1:600,000 and 1:75,000 are mostly used for planning operations, for example, movement and deployment of troops. Large scale maps are the means to meet the tactical and administrative needs of field units. The mostly used scale for this purpose is 1:50,000.

3. Uses of Military Maps

The use of topographical maps as a display can generally be categorized into two main purposes:

a. Briefing: Information transfer to superiors, subordinates or other commanders for coordination. It is particularly important for subordinate commanders to detect and identify displayed troop developments because they are expected to know the overall situation and to transform the given information into action.

b. Situation Reports during Action: Reports have to be evaluated in the context of the given situation in a given terrain. Correct detection and integration of the units reported is essential for rapid decision making.

4. Colors Used in the Design of Maps

a. Hypsometric Maps

One of the primary variables determining the efficiency of map using is the altitude, which is not determined as easily as distance and direction. In addition to the common means to show the vertical position of relief features as hachuring (method of showing closely set parallel lines to represent hill shading) pictorial symbols and contour lines are altitude tints (hypsometric coloring). The conventional color scheme [Ref. 18] is: greens for elevation under 1000 feet; browns, ranging from light to dark, representing elevations generally between 10 and 15,000 feet and white representing elevations over 15,000 feet.

The procedure of layer tinting has been suggested by the military for possible use in jobs of vertical control in a fire center or for ground orientation of observers [Ref. 19]. Kempf and Pook [Ref. 19] conducted an experiment using 12 different hues for altitude levels, and determined that layer tinting of maps did enhance determination of altitudes.

b. Colors Used on Topographic Maps

It is essential for the military to have a general and standardized means to provide terrain information. To allow easy identification of features on maps by providing discriminable symbols and contrast, topographic symbols are commonly printed in different colors each identifying a class of features. As listed in the U.S. Army's Map Reading Field Manual [Ref. 16] the colors used and the features each represents are:

- Black - the majority of cultural or man made features
- Blue - water features such as lakes, rivers, swamps
- Green - vegetation such as woods, orchards and vineyards
- Brown - all relief features (contours)
- Red - main roads, built up areas, and special features

This coding technique has proven to be effective for the purpose of terrain determination and evaluation. In addition to the color coded topographic symbols used on maps, the military requires methods for displaying the identity, size, location and deployment of troops on the battlefield or other areas. Movements and changes have to be indicated. That requires the user either to superimpose those symbols directly or on overlays. In either case they need to be detected and identified on the background of the topographic symbology.

5. Color Coding of Military Symbols

To a certain extent the use of colors has been established within the military. The German Field Manual ZDV 1/11, Nr. 217 [Ref. 20] lays down the application of colors on maps in the following way:

- Black: lines of command

- Blue: friendly troops
- Red: foe
- Green: permanent obstacles, demolitions
- Yellow: contaminated areas

It should be noted that the units either own or foe are encoded in monochrome, blue or red respectively. The discrimination of troop type is done by appropriate symbols. (Fig. 2 illustrates some of the symbology).

6. Application of Color Coded Symbols on Maps

In general, the majority of the literature surveyed concludes that multicolor displays have certain advantages over monochrome displays - either in terms of faster response time or fewer errors, or both. But as yet no specific conclusion related to increment or decrement in performance as a result of color coding or tactical symbols on maps has been inferred.

As Shontz et al. [Ref. 21] suggests the saving in time needed for a search task..."appears to be a function of the efficiency with which search patterns can be structured when color information is available." Considering this basic idea the experiment described in Chapter II was designed to determine whether and to what extent color coding of military symbology on maps can enhance the map reader's performance.

E. CONSIDERATIONS REGARDING THE USE OF COLORED SYMBOLOGY ON MILITARY MAPS

As discussed so far, the effectiveness of human information processing depends largely on information coding in general and the use of color in particular. Results of color coding experiments have shown that multicolor displays offer significant advantages over monocolor displays, but

their application on maps and electronic displays requires some special considerations. When applying color to maps it must be ascertained that:

- a multi-element color code will permit each color to be correctly and reliably identified
- the contrast between the symbols as well as to the colors used for the map background is adequate
- the number of colors used is limited in order to maintain the advantage of an additional coding dimension (interaction between density and code size).

Shape and color are essential properties giving objects their individual character. Color offers a unique contribution to the appearance of the object, providing qualities that shape alone cannot give.

Whether state of the art or conventional, manually constructed displays are employed, the reviewed literature reveals that human operators performance can be increased with respect to certain tasks when color is appropriately applied. This finding is the basis for the current experiment.

F. HYPOTHESES

The experiment described in Chapter II was designed to test the following hypotheses:

Application of color coded symbology on maps would:

1) decrease the response times for identifying and counting units represented by their appropriate symbols

2) increase the accuracy of correct number of displayed units

3) increase the accuracy of location transfer from a display onto a map (identical with the original background map).

II. EXPERIMENT

A. EXPERIMENTAL DESIGN

1. Design

Most military briefing situations require the subjects to transfer information concerning battlefield situations into the details needed for the execution of their task. Essential details include the number and location of military units of both friendly and enemy sides. Speed and accuracy of information transfer are important for subsequent evaluation and tactical decisions. Efficiency is at least partially dependent upon design of displays used to transfer the desired information. Therefore, this experiment was designed to test the differences in detection time, accuracy of response and accuracy of location of detected military units relative to each other using two differently coded displays. The main goal was to determine whether and to what extent redundant coding of military symbology on maps by the use of colors as opposed to standard usage could improve the map reader's performance. Besides expected reduction in detection time and response accuracy it was of particular interest to what extent color coding could improve the determination of location and transfer of symbols from a relatively cluttered display onto a map representing the same area as the given test display by means of pattern recognition.

The hypothesis to be tested was that color coding of military symbols does not have positive effects on operator's performance against the alternative that color coding improves performance. The design is shown in Fig. 1.

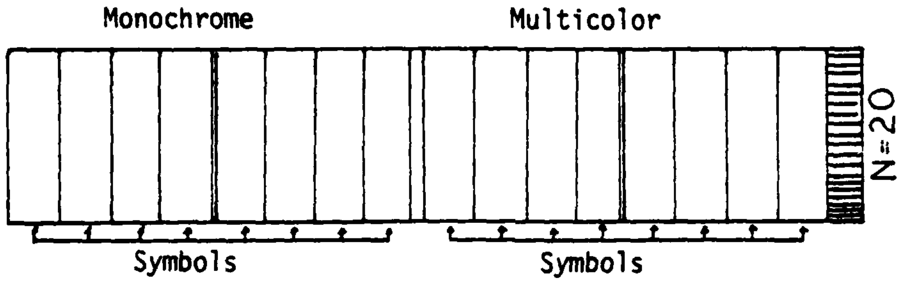


Figure 1: Experimental Design

2. Display and Symbols

The stimuli presented consisted of two sets of four color slides, each showing standard military symbols for five types and units, namely Artillery, Armor, Engineers, Infantry and Mechanized Infantry (Fig. 2). These symbols were chosen because they were typical and the most common units present in general battlefield situations.

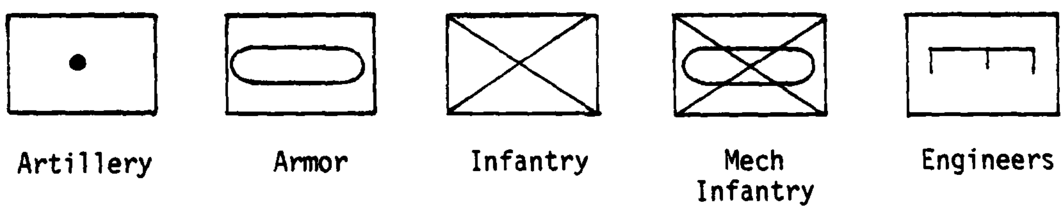


Figure 2: Symbols Used in the Experiment

3. Color Selection

Two sets of symbols, monochrome and colored, were developed. The symbols of the first set were drawn in monochrome fashion for both friendly and hostiles. To identify friendly and enemy forces standard military usage were used, red for enemy and blue for friendly units [Ref. 20]. Despite the application of actually two colors the term

"monochrome" was used since friendly and enemy units were not mixed but merely divided into two groups. Hence all used symbols were drawn in one color only for either side.

The second set used the same symbols as described in Fig. 2 but were color coded. The choice of the colors red, green, blue and orange was based on the criteria described in the previous chapter. They are easily identified under good viewing conditions due to high wavelength separation. The colors used were well saturated and were assigned to the symbols shown in Fig. 3.

The attachment of colors to symbols was arbitrary with the following exception: the Infantry unit is most likely to be deployed in areas covered by forests or similar coverings usually colored green on military maps. In order to avoid the need to apply green on green map background, the color for infantry had to be other than green to maintain the desired contrast.

To allow for identification of friendly and enemy units, single-line symbols were used for friendly units and double-line symbols for enemy units on the second set according to military standard Ref. 22 . In order to keep the symbols at the same size, the second line for enemy units was drawn inside of the original symbol.

4. Symbol Presentation

Two sets of four slides each were prepared. The symbols described in the previous section were superimposed on a background map (see next section). Both sets of slides were identical with respect to number of units and location. The fifth symbol, Engineers, which was coded in black for both sets of slides, was not subject to the test, it merely served at additional background disturbance (noise).

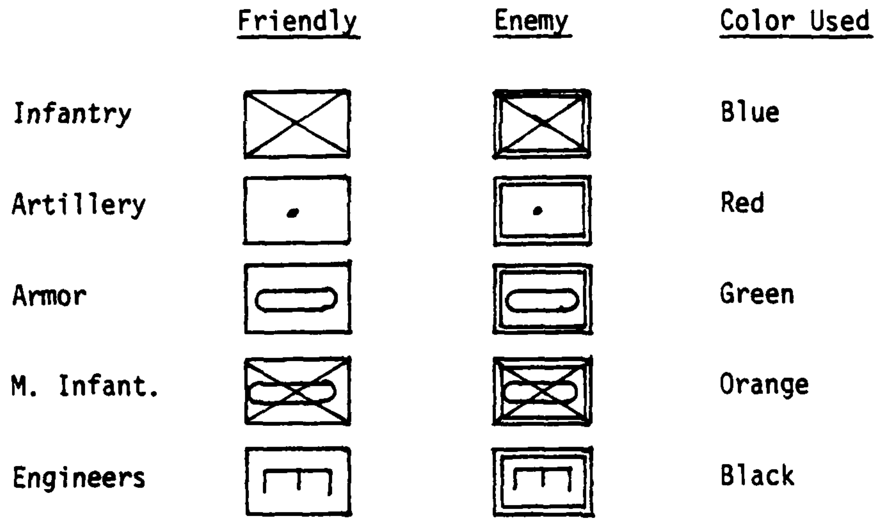


Figure 3: Symbology Used to Differentiate Friendly and Enemy Forces

The number of symbols on the four slides of each set was different. The total symbol density (enemy and friendly units) was 33, 36, 39 and 42 for slides 1, 2, 3 and 4. The content of the four slides listed by symbols is shown in Table 2.

Hemingway and Kubala Ref. 1 in a study comparing conventional symbols to an alternative set of symbols found that the artillery symbol was perceived more accurately than any of the other symbols. They assumed that this was likely to be a function of the nature of battlefield

Table 2
Number of Units for Each
Symbol Type

Slide	Friend					Foe				
1	3	4	4	3	3	2	3	4	4	3
2	3	4	4	3	4	4	3	4	4	3
3	5	4	4	3	4	4	3	5	4	3
4	5	4	5	3	4	4	3	5	4	3

situations where the artillery tends to be further back on both sides than other units and thus perhaps easier to locate. To avoid this effect and since the objective of this thesis was to test differences between two differently coded symbol sets without special regard to type of symbol, the symbols used were deployed on the map in a random fashion rather by typical tactical considerations with the constraint that friendly forces were deployed to the left of the display while the enemy forces were on the right.

5. Background Map

The map used to represent the hypothetical battlefield area was a German military map sheet "VECHTA", sheet Nr. L 3314, scale 1:50,000. The colors used on this map were in accordance with the Army's Field Manual FM 21-26 [Ref. 16], as described in the previous chapter.

This sheet was chosen because it represents the colors black, red, green and blue in an about evenly spread fashion as well as it contains streets, small towns and villages which can be considered as representative of much of Northern Germany. The freeway running from the North to the South in the middle of the map sheet served to divide the forces into two sectors. The topographic features represented on the right side (enemy) of the map were somewhat more dense than on the left side (friendly). The symbols (14x9mm) were drawn on transparent plastic sheets and randomly placed on the map, differently for each of the four slides, which were produced using 35mm EKTACHROME-Film. A sample display is shown in Appendix A.

B. METHOD

1. Projection and Timing System

The apparatus used to present the stimulus slides and to measure the detection times consisted of the items as shown in Fig. 4. The

leftmost portion of Fig. 4 shows the items listed below from top to bottom:

- Kodak Carousel Projector fitted with a Lafayette shutter (Lafayette Instrument Co.)
- Counter/Timer Model Monsanto 101 b
- Digital Printer Newport 810
- Logic Interface (Controlling Timer, Printer and Shutter).

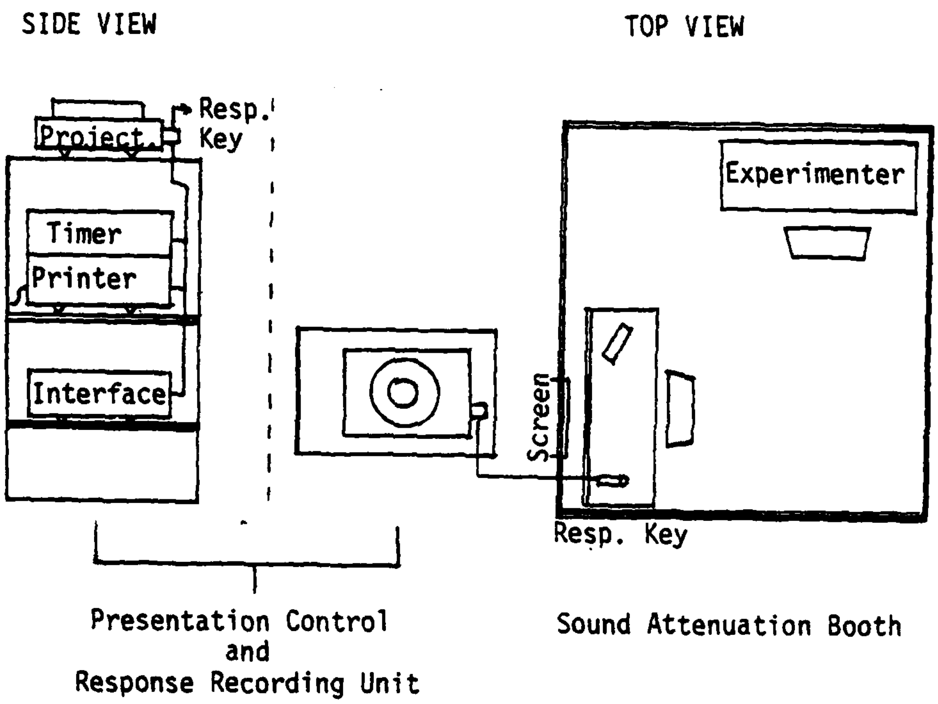


Figure 4: Arrangement of Experimental Apparatus

The projection apparatus was set up in front of an IAC Controlled Accoustical Test Booth. Slides were rear projected through a two-way mirror separating projector and test room, onto a 10 x 14.4

inch screen. The subject viewed the display from a seated position behind a table on which a response key was positioned. When initially depressed, the response key opened the shutter and started the timer. Pressing the key a second time closed the shutter and stopped the timer. The stimulus presentation time was then printed out by the printer at an accuracy of 1/1000 of a second. A 15 watt shaded lamp was placed on the table to give sufficient light to mark the provided test sheets.

2. Subjects

Twenty Naval Postgraduate School students participated in the experiment. Ages ranged between 27 and 38 years. All were military officers from different countries (USA 13, Germany 5, Norway 1, Turkey 1). The major criterion for selection was that none of them had previous experience with Army-related symbols and maps so as to have a group of quasi-naive subjects. Therefore, the participating officers were either in the Navy, Air Force, Coast Guard or Aviators in the Marine Corps. Prior to the experiment, all subjects were questioned about color or acuity deficiencies. All participants had normal color vision, and normal or corrected (20/20) visual acuity. All subjects were volunteers and received no compensation for participation.

3. Procedure

Each subject was seated with his eyes approximately 80 cm from the projection screen and was unrestrained by headrest or bite-board which more closely approximated the real-world situation. The size of the projected symbols measured on the screen was 12 x 8 mm, subtending approximately 50 minutes of arc in width and 35 minutes of arc in height. The experimenter was seated in the testbooth at a different table.

Each subject served as his own control and performed the second part of the experiment seven days after the first test at the same hour at which he had initially been tested. Ten of the subjects were given monochrome set of slides first and ten the color coded set first to ensure cancellation of possible learning effects.

a. Training

Subjects were first presented a slide with the appropriate symbols, which was explained to them in accordance with a prepared instruction sheet. After the subject felt he knew the different symbols, a test slide was shown representing a background area different from the actual test slide. In this case the dividing center line was a clearly visible river running from North to South. The experimenter pointed at the different symbols and asked the subject to describe verbally the symbol for each unit, and any errors were corrected. The additional purpose of this test slide was to make the subject familiar with the kind of test he was expected to perform. He was told that all of the friendly units were west of the center line (river, later freeway) and the enemy units east of the line. Next he was told that he was going to see a second test slide with differently positioned units. The following instruction was given:

"You will have a maximum of 10 seconds to view the slide and to answer each of the following questions. When you have understood the question and you feel you are ready, press the key you are holding to present the display and to activate the timer. Try to find the answer to the question as fast and as accurately as possible. Speed is important, but speed without accuracy is not desired. As soon as you

think you know the answer press the key again and then answer the question verbally or mark the map sheet in front of you accordingly."

Next the subject was given four copies (11 x 8.5 in) of the map section shown on the slide and expected to transfer the detected units onto his copy by simply making crosses after he had pressed the response key the second time. After the warm-up and learning phase was performed, the actual test was conducted.

b. Test Conditions

Each subject had to answer a total of 20 questions, five for each slide. The questions asked per slide consisted of 3 different types. Two questions were related to the number of symbols, two questions to the location and one question to the ratio between enemy and friendly forces. Both the sequence of the slides as well as the sequence of questions within each slide was totally randomized and different for each subject. To determine the slide sequence, a table of 24 combinations was constructed and numbered from 1 through 24. Using the Random Number Generator for the uniform distribution between 1 and 24, the sequences for each subject were chosen. The same procedure was applied to determine the sequence of questions per slide by construction of a table of 124 possible combinations and using the same Random Number Generator (TI 59). The subject was neither informed about the number of the slides per set nor about the number of questions. A sample of questions asked is presented below:

1. How many friendly Artillery units are there?
2. What is the ratio of friendly Infantry to enemy Armor?
3. Where are the enemy Infantry units?

4. Where are the friendly Armor units?

5. How many Mechanized Infantry units are there?

A complete set of questions will be given in Appendix B.

After the subject had answered the second question of the location-type (where), he was asked to turn to the next blank map sheet. Since the sequence of the questions was randomized this procedure made sure, that the subject was unaware of the change of slides controlled by the experimenter after each block of the questions. After completion of the sequence of 20 questions, the printer output containing the response times was attached to the subject's questionnaire along with the four completed map sheets.

4. Measures

a. Time

The subject controlled the measurement of the times required to answer the question by pressing the response key. The times measured were divided into 3 categories:

1) Time required to answer questions of type 1 (Number)

2) Time required to answer questions of type 2 (Location)

3) Time required to answer questions of type 3 (Ratio)

Although the tasks of question type one and type two seem to be similar, it was assumed that the location task would require more time since the subject was expected to apply some strategy to identify the location and to transfer the locations onto his answer map.

The type 3 question was expected to require more time to answer because the subject had to concentrate on two different symbol types, approximately twice as many as in the type 1 question task.

b. Accuracy of Counting

The second type of measurement was the accuracy of response with respect to number of symbols displayed. The criterion was whether the subject reported the correct number of units or not (dichotomized).

c. Accuracy of Location

Finally, the third type of measurement was the accuracy of symbol transfer from the displayed slide onto a copy of the background map of the display. To measure this, transparent overlays were produced in the following way: the original slides were projected on the same type of copy as provided to the subjects and the appropriate symbols in turn were copied on clear plastic sheets. Around the center of each symbol three circles of diameters .75, 1.25 and 1.5 inches were drawn as shown in Fig. 5.

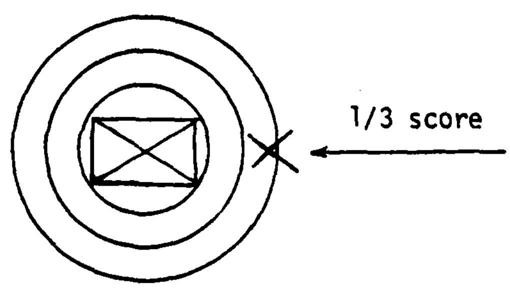


Figure 5: Example for Measurement of Accuracy of Location

Depending on whether the center of the subject's mark was within the inner, the middle or the outer circle, a score of 1, 2/3 or 1/3 was assigned. Since the total number of symbols each subject was asked to locate for both set 1 and set 2 was 32, the maximum attainable score was 32.

III. ANALYSIS AND RESULTS

The verbal responses and response times provided by the digital printer for each question were recorded on separate answer sheets for each subject. Next, all data were transferred to separate master sheets on which the response times were recorded by question type. The results of the analysis of the response time data will be discussed first, followed by analysis of the accuracy data and finally by a discussion of the accuracy of location transfer data.

A. RESPONSE TIMES

1. Data Analysis

The response times of each subject are listed in Appendix C. Table 3 presents the summary statistics for the total response times. The data represent the average of all questions with respect to time. Since each subject had to answer 20 questions, a total of 400 data for both the monochrome and the multicolored sets were collected. The mean differences between the two sets should be considered in the light of the time limit established for the test condition. The allowed maximum time of 10 seconds to answer the question yielded many truncated data, particularly for question type 3 (Ratio) in the monochrome set. A more detailed analysis by question type revealed adequately more pronounced differences as shown in Table 4.

Table 3
Mean and Standard Deviation of Response Times for All Questions

Mean Cumulative Response Time Per Subject

Monochrome		Multicolor	
$\bar{X}$	6.97	$\bar{X}$	5.47
s	2.17	s	2.10

Mean Cumulative Response Time Per Subject to All 20 Questions

Monochrome		Multicolor	
$\bar{X}$	139.4	$\bar{X}$	109.39
s	16.45	s	17.98

$\bar{X}$ = Sample Mean

s = Sample Standard Deviation

Table 4
Mean and Standard Deviation of Response Times for Each Question Type

Question Type 1 (Number)

Monochrome		Multicolor	
$\bar{X}$	5.345	$\bar{X}$	4.06
s	1.583	s	1.466

Question Type 2 (Location)

Monochrome		Multicolor	
$\bar{X}$	7.407	$\bar{X}$	5.780
s	1.775	s	1.773

Question Type 3 (Ratio)

Monochrome		Multicolor	
$\bar{X}$	9.345	$\bar{X}$	7.667
s	.934	s	1.466

$\bar{X}$ = Sample Mean

s = Sample Standard Deviation

a. Test for Normality

The raw data for the search times revealed some outliers in the multicolored set and several truncated data in the monochrome set, i.e., the subjects used the total time of 10 seconds to respond. Therefore, a common logarithmic transformation was applied to the raw data to restore homegeneity of variance and near normality.

Appendix D shows the normalized data plotted versus the transformed raw data and checked for normality by applying a chi-square test. For both the monochrome and the multicolored set the data of question type 1 (Number) and type 2 (Location) did not show any indication of non-normality. The relatively straight lines as well as the Chi-Square values attained do not stress the need to reject the assumption of normality. However, the data of question type 3 (Ratio) for both sets do not allow the assumption of normality when comparing the Chi-Square value to the critical value of 14.1 for 7 degrees of freedom. A closer look at the plot (Appendix D), however, shows that the non-normality is very likely due to the proportion of truncated data (subjects did not respond within the given 10 seconds or tended to respond at the end of the time. The maximum time of 10 seconds was used 34 times for the monochrome set and 7 times for the multicolored set.

b. Test for Homogeneity of Variances

In addition to normality, homogeneity of variances is required for the application of parametric statistical tests. In order to compare the variances of both the monochrome and the multicolored sets, the following hypothesis was tested:

Ho: The variances are equal

using the F-Distribution at an Alpha-level of .05 [Ref. 23].

This resulted in a F-Ratio of 1.346 and a sampling distribution of F(399, 399). Since the corresponding probability is greater than .95 and less than .05 (TI-59, PGM 22), it is in the critical region. Therefore, Ho is rejected and equality of variances is not concluded. Separating data of type 3 question (Ratio) from the rest, clearly shows that this is due to the Ratio-data containing many truncated response times. Application of the same test as above to the combined data of question type 1 and 2 (number and location) resulted in a F-Ration of 1.28 and a sampling distribution of F(319, 319). The corresponding probability is less than .95 and greater than .05; hence, it is not in the critical region. Therefore, equality of variances for these data can be concluded; however, not for the data pertaining to question type 3 (Ratio). The result of these data showed a F-Ratio of .3362 which is in the critical region. Hence, parametric statistical tests should be applied only with caution.

2. <u>Tests of Significance</u>

The hypothesis to be tested was:

Ho: The application of redundant color coding of conventional military symbols has no effect on the response time of subjects.

The alternative hypothesis was:

H1: The application of redundant color coding of conventional military symbols does have effects on the response times of subjects.

a. Nonparametric Test for Response Times

Because all of the necessary requirements for the parametric t-test were not met, the nonparametric Wilcoxon Matched-Pairs Signed-Ranks

Test [Ref. 24] was applied to test for differences between the monochrome and the multicolored sets with respect to time.

The test statistic for this test is computed by the formula

$$Z = \frac{T - \frac{N(N+1)}{4}}{\sqrt{\frac{N(N+1)\ (2N+1)}{24}}}$$

where

N = number of subjects

T = Sum of the rank with less frequent sign.

For N of this size the sum of the ranks is practically normally distributed with zero mean and unit variance (Siegel, 1959).

The following data were used:

Alpha = .05

N = 20

T = 1

This resulted in a Z-value of -3.88. The corresponding probability is less than .0001. Therefore, the Null hypothesis of no differences is rejected.

Testing the data separately by question type resulted in similar values, the differences were significant at levels less than .0002. The corresponding Z-values were -3.92 for type 1 (Number), -3.55 for type 2 (Location) and -3.92 for type 3 (Ratio) data respective.

b. T-Test for Response Time Data

As a double check, the parametric correlated t-test was applied to the total set of the transformed raw data, since for the

Wilcoxon test the row sums of the actual response times per subject were used.

The statistic for this test is computed by the formula

$$t = \frac{\overline{X}_2 - \overline{X}_1}{s_d \sqrt{N}}$$

where $\overline{X}_1$ and $\overline{X}_2$ are the means of the response times of set 1 and set 2 (monochrome and multicolor) respective.

N = Number of response times.

S = Standard deviation of the differences.

Using the values of the transformed data

$$\overline{X}_2 - \overline{X}_1 = .2647;\ s_d = .34928 \text{ and } \sqrt{N} = \sqrt{400} = 20$$

a t-value of 15.157 was attained. Since the critical value at Alpha .05 is approximately 1.64, the difference of the means is about as significant as found using the Wilcoxon test. The hypothesis of no differences was again rejected.

c. Analysis of Variances

In order to determine the more detailed effects of multicolor coding versus single color coding the 20 questions were divided into five blocks. In each block an individual's score was the sume of the response times with respect to type of question additionally separated by friendly and enemy forces as shown in Figure 7. A check of the data by plotting the normalized data used in the block design against the actual data exhibited evidence sufficient to assume normality (Appendix E). As Dixon and Massey [Ref. 23] state, the results of Analysis of Variance using the

F-Distribution are changed very little by moderate violation of the assumptions of normality and equal variance.

	Question Type				
	Type 1 (Number)		Type 2 (Location)		Type 3 (Ratio)
	Friendly	Enemy	Friendly	Enemy	Friendly Enemy
Mono					
Color					

Figure 6: Block Design for ANOVA

F-Distribution are changed very little by moderate violation of the assumptions of normality and equal variance.

The results of the ANOVA shown in Table 5 confirmed the significant difference between the two coding techniques, since the obtained F-ratio of 98.19 exceeds the critical value for $F_{.95}(4, 190)$ of approximately 2.42 (F-Distribution PGM 22, TI-59). The F-ratio for the interaction of sets and type of question is 1.14 and not significant at the .05 level.

Table 5
ANOVA for Monochrome vs. Multicolor Sets by Question Type

Source	SS	DF	MS	F	P
Monochrome/ Multicolor Sets	1801.62	1	1801.62	98.19	2.3^{-11}
Question Type	6570.92	4	1642.73	89.53	1.23^{-42}
Interactions	83.77	4	20.94	1.14	.34
within (error)	3486.30	190	18.35		
Total	11942.61	199			

Question Type: Number, Location (Sep. by friend, enemy)
Ratio (Comb. friend/enemy)

A comparison of the mean differences between enemy and friendly forces and between set 1 (monochrome) and set 2 (multicolor) showed more detailed results. A complete table summarizing the statistical procedure and results is contained in Appendix F. To determine significance of differences, the following formula was used [Ref. 23]:

$$- \frac{qs}{\sqrt{n}}$$

where q = percentile for number of means and degrees of freedom obtained in the ANOVA (within)

s = within MS, obtained from ANOVA

The data used for this comparison were:

$$q_{.95}\ (10,\ 190) = 4.47$$

$$s = 18.35 \qquad = 4.28$$

$$N = \qquad = 20$$

The comparison resulted in no differences between friendly and enemy units for either the monochrome or multicolor set, since all of the appropriate confidence limits as shown in Appendix F cover zero. The comparison of symbol sets resulted in significant differences between all but one subset. The differences between friendly units of the multicolored set for question type 1 (Number) were not significant at the .05 level (but were at .1). The bar graphs in Fig. 7, illustrating the differences between the unit types of the monochrome and the multicolored sets, shows that the above finding is very likely due to the simplicity of the Artillery symbol. The same assumption seems to be true for Artillery and question type 2 (Location) as shown in Fig. 8. Fig. 9 shows the relatively even proportions of differences between the sets for question type 3 (Ratio).

Generally the symbol for Artillery was perceived much faster than others in both sets. The overall recognizability of this symbol was

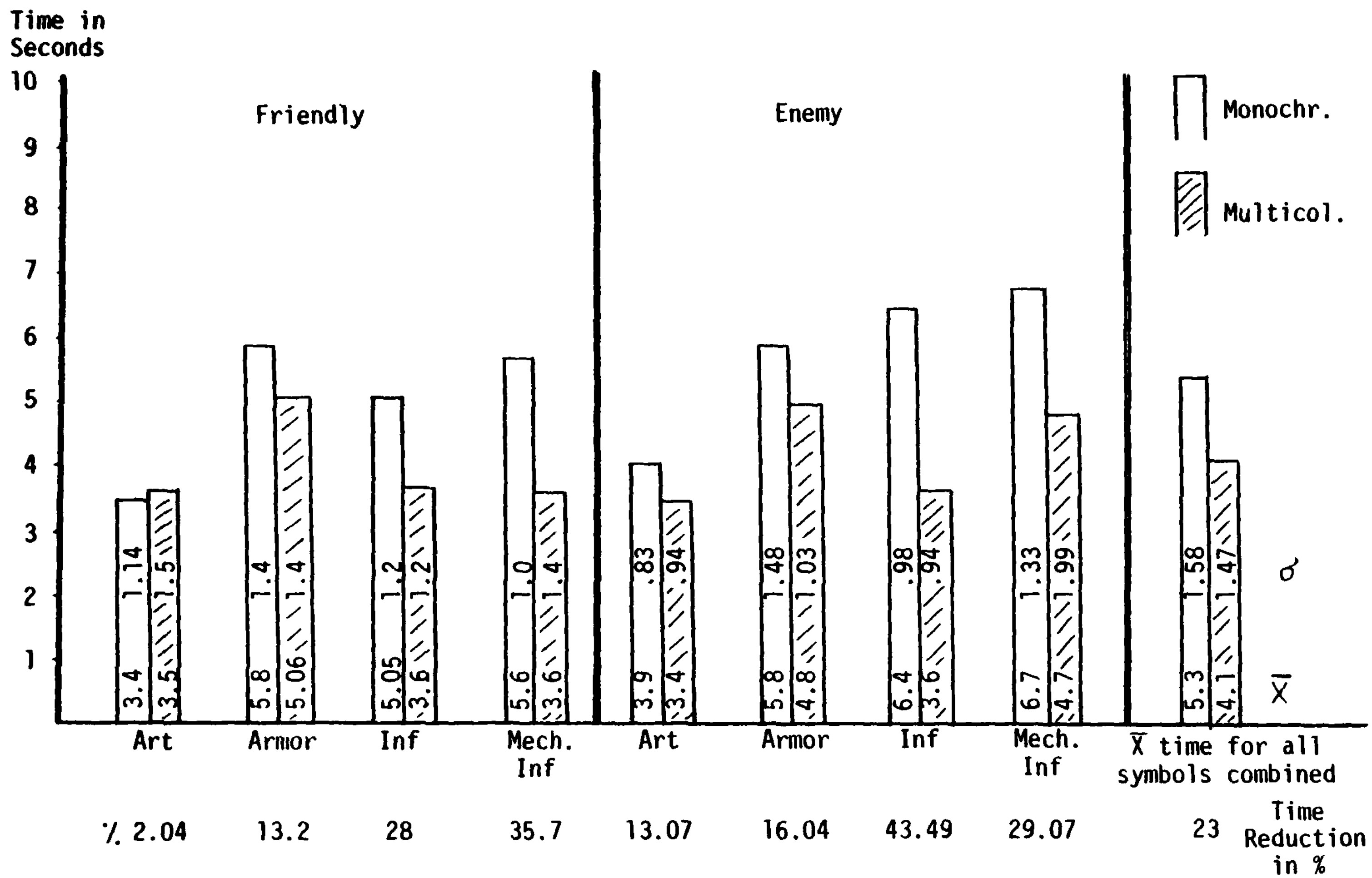


FIGURE 7: Response Time on the Counting Task (Question Type 1) To Monochrome and Multicolored Symbols

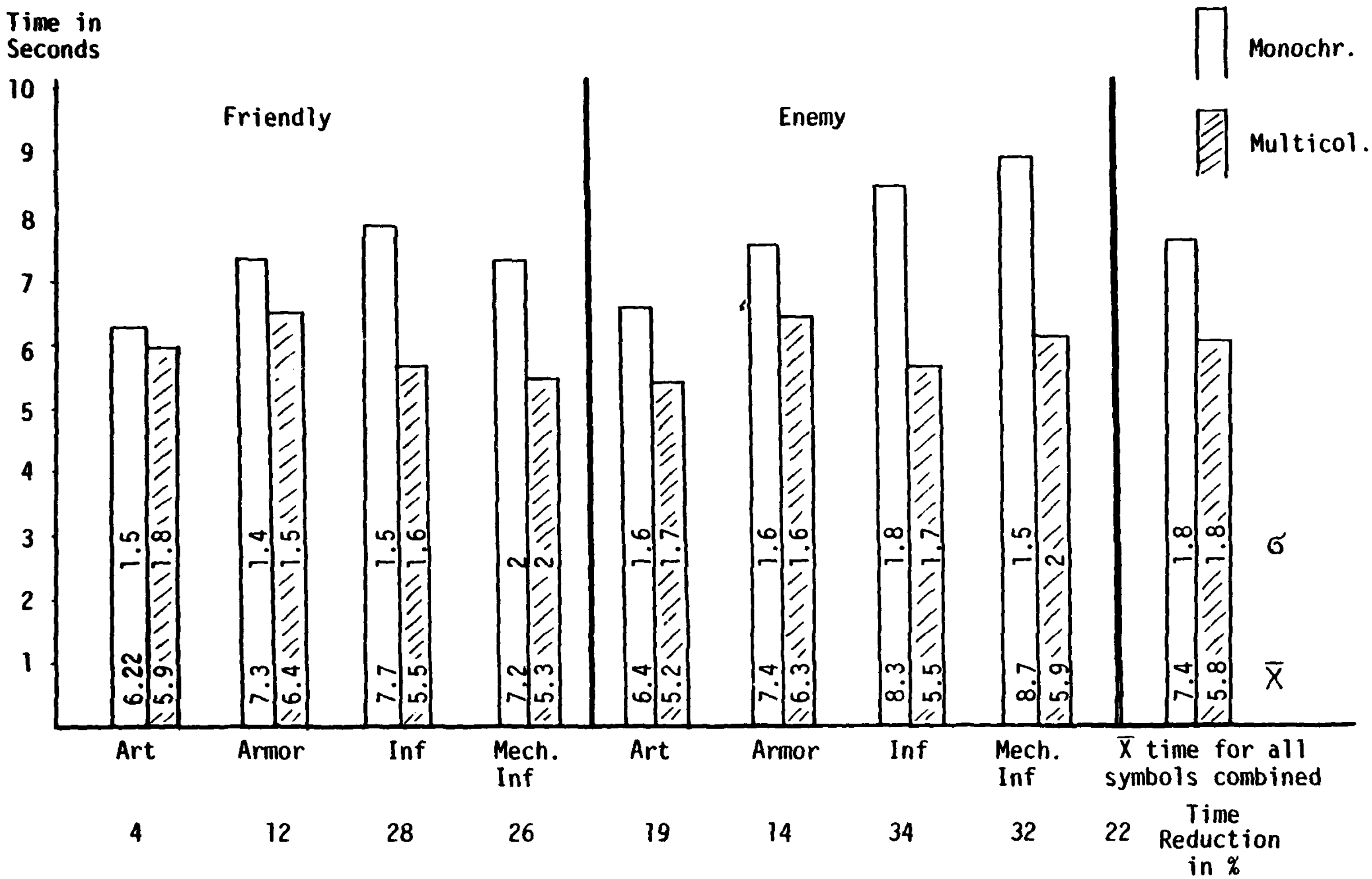


FIGURE 8: Response Time on the Location Task (Question Type 2) To Monochrome and Multicolored Symbols

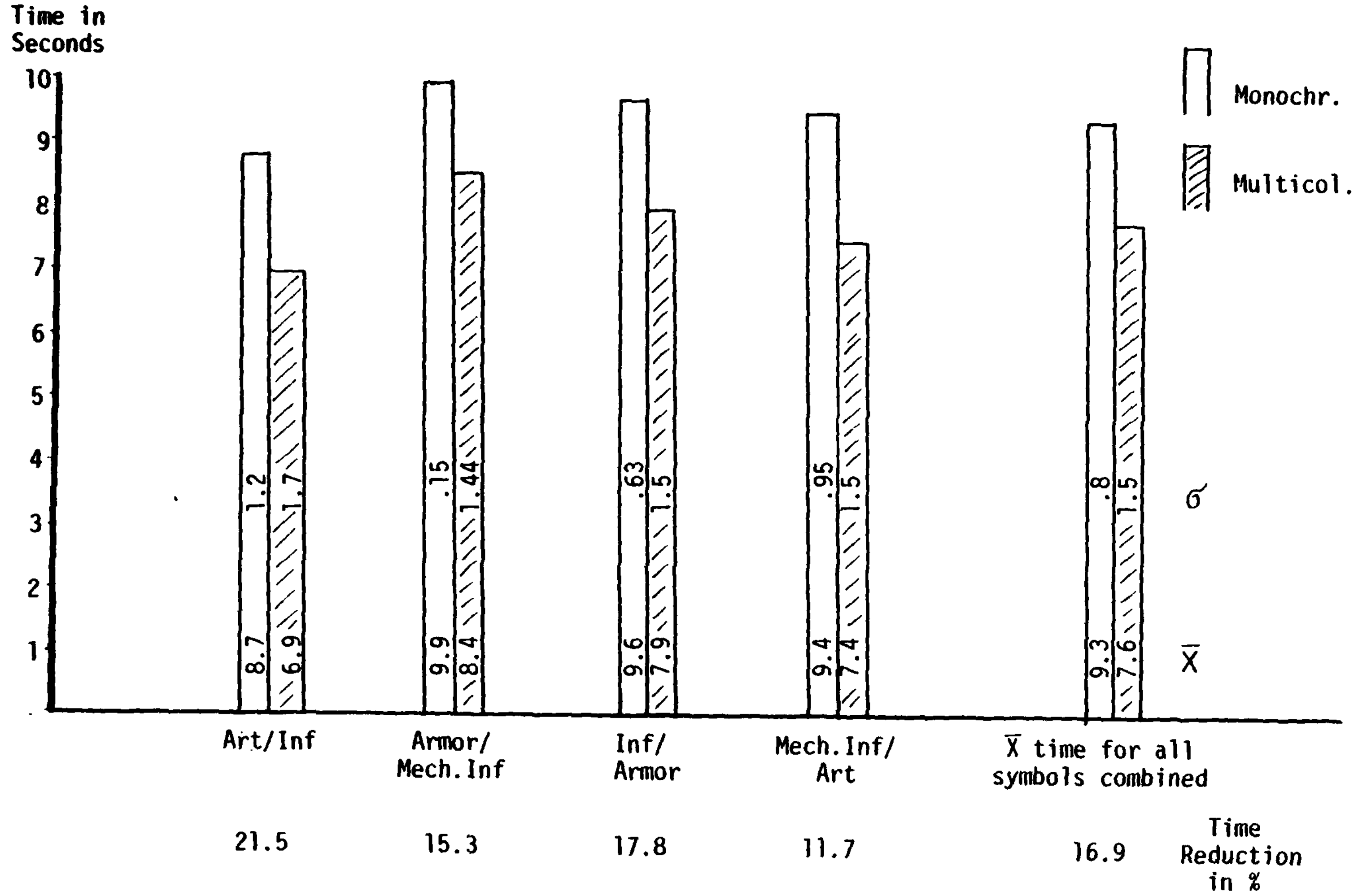


FIGURE 9: Response Time on the Counting Task (Question Type 3, Ratio) to Monochrome and Multicolored Symbols

only slightly improved by using color coding. Stronger differences in favor of color coding were found on the enemy's side what seems to be a function of background density, which was somewhat higher on the right side of the display.

B. ACCURACY OF RESPONSE

Table 6 lists the summary statistics for the total accuracy of responses for the monochrome and the multicolored sets. The hypothesis to be tested was:

Ho: Multiple color coding of military symbols has no effect on the accuracy of the number of units detected

versus the alternative

H1: Redundant color coding of military symbols does effect the accuracy of the number of units detected.

Applying the Wilcoxon Matched-Pairs Signed-Rank Test to the total scores as well as to the scores of question types of both the monochrome and the multicolored sets resulted in significant differences at levels much smaller than .05.

The Z-value obtained depends highly on the T-value, that is the sum of the rank of the differences with less frequent sign. The T-value for the scores of question type 1 (Number) was 1 and for question type 2 (Location) it was 2, yielding the lowest Z-value of -3.85 with the corresponding probability of .00007. Hence, the hypothesis of no differences in accuracy of reporting the number of units detected was rejected. A table of the scores for accuracy is liested in Appendix G.

Figure 10 exhibits the differences between the monochrome and the multicolored sets by question type with respect to number of correct responses per type of question. Figure 11 shows in more detail the

Table 6
Mean and Standard Deviation of Correct Responses Per Subject

1. Mean Accuracy of Responses (20 Questions)

	Monochrome		Multicolor
$\overline{X}$	14.55	$\overline{X}$	18.20
s	2.33	s	1.64

2. Mean Accuracy of Responses by Question Type

a. Type 1 (Number) 8 Questions

	Monochrome		Multicolor
$\overline{X}$	6.15	$\overline{X}$	7.60
s	1.27	s	.50

b. Type 2 (Location) 8 Questions

	Monochrome		Multicolor
$\overline{X}$	6.15	$\overline{X}$	7.30
s	1.12	s	.66

c. Type 3 (Ratio) 4 Questions

	Monochrome		Multicolor
$\overline{X}$	2.25	$\overline{X}$	3.30
s	.85	s	.81

differences with respect to the particular symbols. The vertical axis shows the number of subjects who responded correctly. Obviously the difference in accuracy between both sets was less for Artillery. The highest differences in scores were related to the symbols for Infantry and Mechanized Infantry, very likely due to the similarity and the dominance of the diogonal lines. The additional coding dimension color seemed to be particularly helpful in discriminating these symbols.

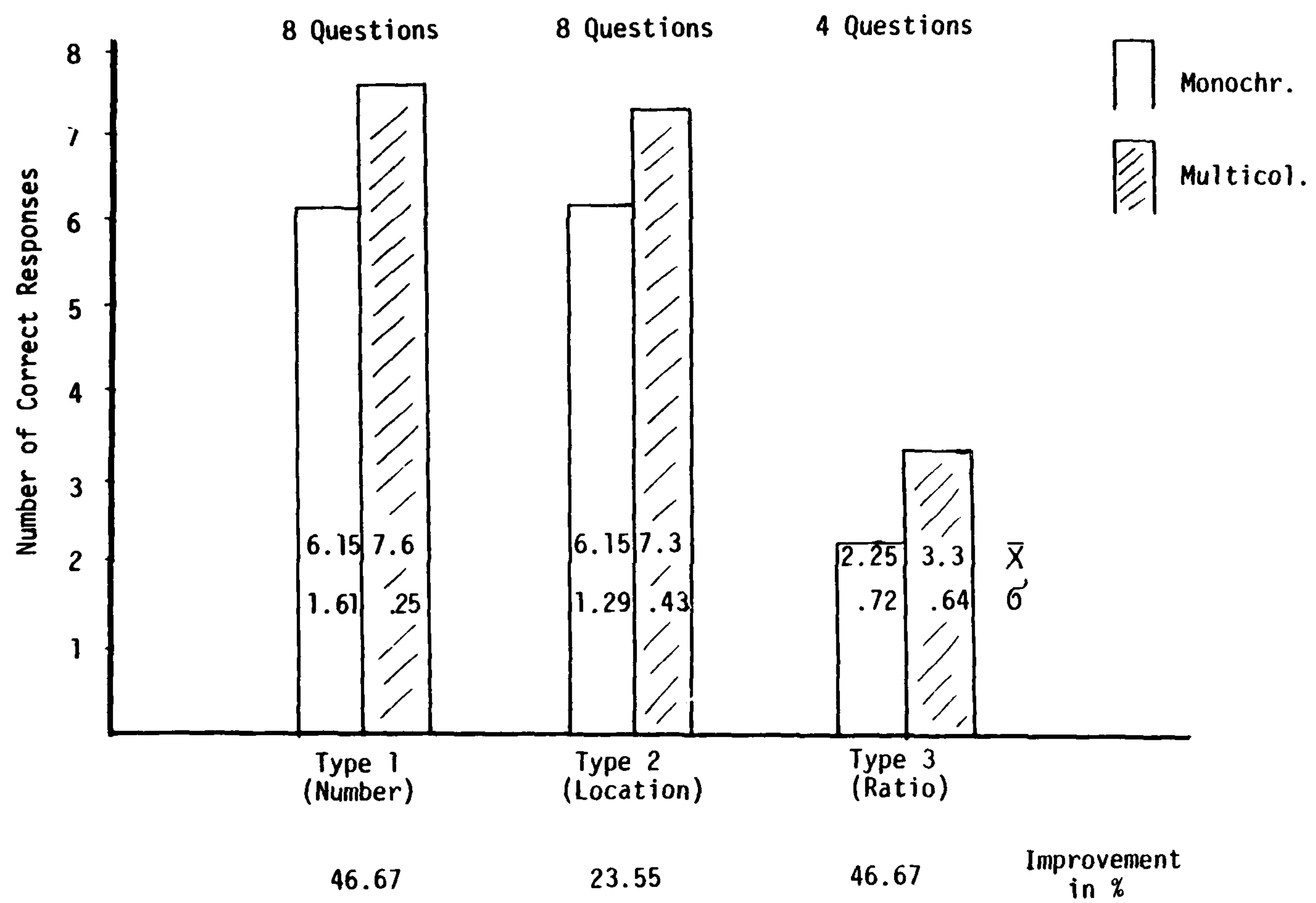
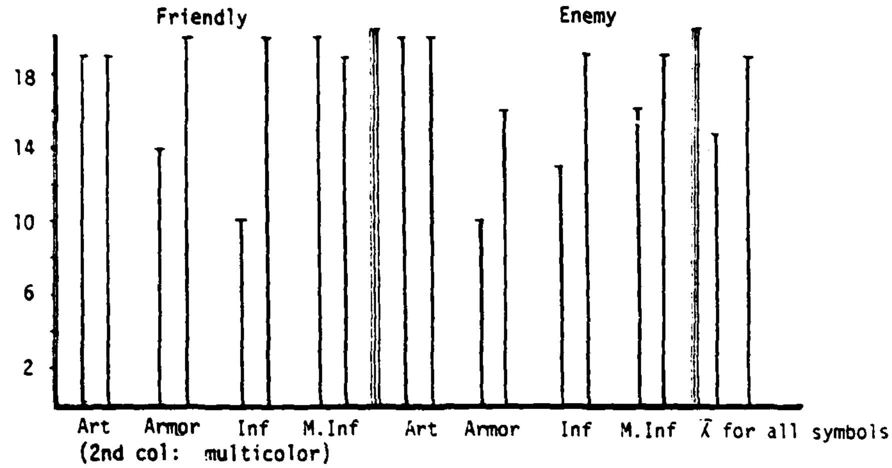
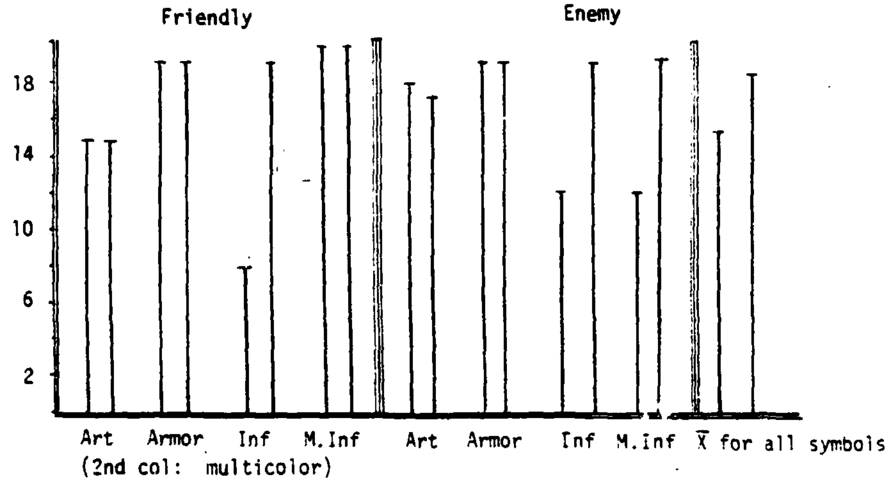


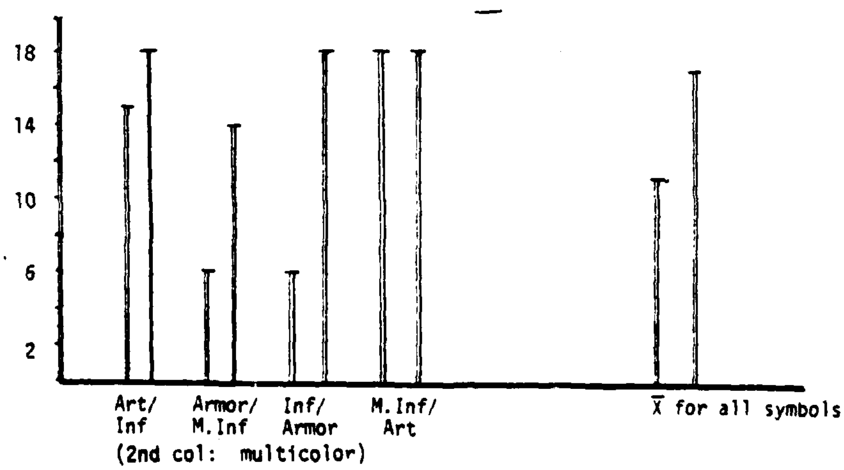
FIGURE 10: Number of Correct Responses Per Question Type



NUMBER OF UNITS - MEAN IMPROVEMENT: 25%



LOCATION OF UNITS - MEAN IMPROVEMENT: 19.52%



RATIO OF UNITS - MEAN IMPROVEMENT: 51%

FIGURE 11: Number of Subjects Responding Correctly to Each Symbol under Each of Three Question Type Conditions

C. ACCURACY OF LOCATION TRANSFER

The third aspect of interest was the accuracy of transfer from the presented display onto a given copy of the background map. The hypothesis to be tested was

Ho: Redundant color coding of military symbols does not affect the accuracy of identification and transfer of the unit's relative location on maps

versus the alternative

H1: Redundant color coding of military symbols increases the accuracy of identification and transfer of the unit's relative location on maps.

Besides the variables speed and accuracy in counting, the matter of interest was the precision of determining the relative location of units to each other within a relatively short period of time.

The total number of units which were to be detected and transferred was 32 for each subject. Table 7 shows the summary statistics of the results for both sets, single colored and multicolored. Appendix H contains the scores for subjects and symbols.

Table 7
Mean and Standard Deviation of Accuracy of Location Scores

Monochrome		Multicolor	
$\bar{X}$	14.28	$\bar{X}$	18.51
s	3.66	s	3.83

Figure 12 exhibits the score differences between the single and multicolored sets by symbol types in percent. Since the total number

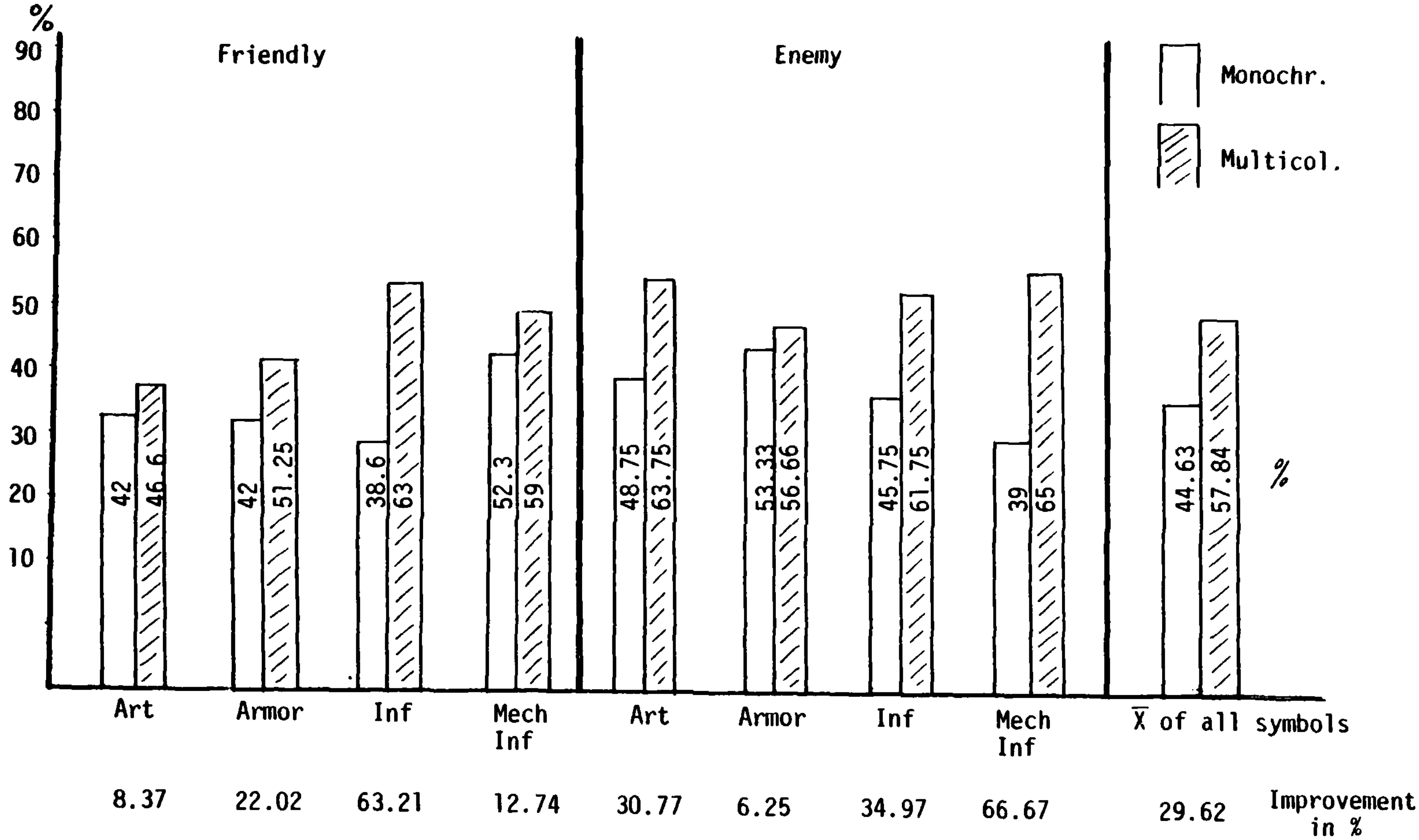


FIGURE 12: Percent of Symbols Whose Location Was Correctly Transferred Under Monochrome and Multicolor Conditions

for each symbol was not the same, only the total scores for each subject were compared. A combined comparison of the means by using ANOVA seemed to be inappropriate since the means of different symbols had to be different due to inhomogeneity of the number of symbols in the display. Furthermore, tests of the data did not allow the assumption of normality. To test for significance of the total differences the Wilcoxon Matched-Pairs Signed-Rank Test was applied. The values used were

$N = 20$

$T = 14$

which resulted in a Z-value of -3.397 with a corresponding probability of .0003. Since this is less than Alpha = .05, the hypothesis of no differences was rejected.

Table 8 shows the results of the comparisons of the individual symbols of the monochrome set to those of the multicolored set by applying the Wilcoxon Matched-Pairs Signed-Ranks Test. Although for each symbol the mean accuracy scores of the monochrome set were higher than the scores of the multicolored set, the differences for friendly Artillery, friendly mechanized Infantry and enemy Armor were not significant at the .05 level. The difference of only 4.6% for the Artillery symbol might be due to the relatively good overall recognizability of this symbol. In the case of the friendly mechanized Infantry the relatively high accuracy of 52.3% for the monochrome set might be due to the small number (N=3) of symbols per slide in combination with the less cluttered map background on the friendly side. So the total difference was only 6.7% despite the relatively high accuracy of 59% for the color coded symbol. The same might

be true for the Armor symbol on the enemy side. The number of symbols was also only 3 resulting in a similar high accuracy of 53.3% for the monochromatically coded symbol. On the more cluttered map background the color green might not have been that effective as the remaining colors red, blue and orange.

Table 8
Significance of Differences in Accuracy of Location between Monochrome and Multicolored Symbols

	Friendly	Enemy
Artillery	$p = .39$	$p = .004$
Armor	$p = .041$	$p = .24$
Infantry	$p = .005$	$p = .017$
Mech. Infantry	$p = .28$	$p = .003$

IV. SUMMARY AND CONCLUSION

A. FINDINGS

The underlying hypotheses of the experiment were that application of color coded symbology on maps would (1) decrease the response times for identifying and counting units represented by their appropriate symbols, (2) increase the accuracy of reporting the correct number of displayed units, and (3) increase the accuracy of location transfer from a map display onto a copy of the map.

Twenty subjects, serving as their own control were shown two differently coded (monochrome and multicolored) sets of slides. Ten of them were given the monochrome set of slides first and ten the color coded set first to ensure cancellation of possible learning effects. The twenty questions each subject had to answer consisted of three different types. Eight questions were related to the number of symbols, eight questions to the location, and four questions to the ratio between enemy and friendly forces. Responses were recorded in terms of time and accuracy.

In general, the outcome of the experiment suggested that the application of color coding to military symbols can improve human performance with respect to speed and accuracy. The more detailed results will be summarized and discussed in the following paragraphs.

1. Response Times

The results of the analysis of response times clearly supported the hypothesis that use of color as an additional coding dimension to

features on the enemy side as well as to the double lined drawn symbols representing enemy units.

2. Accuracy of Response

The accuracy of responses with respect to the number of units correctly identified was significantly higher for the total number of the multicolor coded symbol set, but not for all symbols individually. The accuracy of responses to the Artillery symbol was the same for both the monochrome and the multicolor coded sets with regard to question type 1 (Number). The same was true for question type 2 (Location) for Artillery and Armor as well as for mechanized Infantry on the friendly side. The highest differences in scores were related to the symbols for Infantry, very likely due to the similarity and the dominance of the diagonal lines. The additional coding dimension color seemed to be particularly helpful in discriminating these symbols.

3. Accuracy of Location Transfer

As hypothesized, the accuracy of location detection and transfer was also significantly higher under the multicolor condition. Individual comparisons by symbol resulted in higher accuracy scores for all symbols but not significantly at the .05 level for friendly Artillery, friendly mechanized Infantry and enemy Armor. The transfer of detected symbols from the given display onto a map is crucial and the performance depends highly on the technique the individual applies. Some subjects tried to identify certain area features related to the detected symbol when marking their control sheet. Others, seemingly the majority, tried to transfer the recognized pattern formed by the symbols and their relative location to each other onto their answer sheet accordingly. Even though the difference between the monochrome set and the

multicolored set with respect to scores achieved was statistically significant, the actual differences of scores was not striking, since a score of 1 per symbol was far less frequently attained than 1/3 or 2/3 of a score in both sets. The answer sheets of the multicolored set revealed more often the typical deployment shape as shown on the test slide though not necessarily related to the corresponding geographical locations of the map. However, the outcome suggested that color coding of symbols can improve the accuracy of transfer of the pattern of detected symbols.

The method of scoring the position accuracy was reasonable but arbitrary. More detailed study will be necessary to determine to what extent color coding of military symbols can improve this task in a limited time span.

B. LIMITATIONS OF THE EXPERIMENT

The statement that color coding of military symbols is superior to other coding techniques cannot be generalized. The following limitations have to be taken into account:

1. Selection of Stimuli

Besides the effect of color, the symbol itself affects the recognizability and discriminability. Although the symbols used in the experiment are most common for army purposes, they represent only an arbitrary sample out of a large set of available symbols. The effect of the combination of color and symbol was not tested. The underlying hypothesis was rather that the application of any sufficiently discriminable color to symbols would have positive effects. The problem of which color fits which symbol best should be the subject of further studies.

discriminable symbols does facilitate the speed with which symbols can be located. Differences between the monochrome and the multicolored sets were very significant for all symbols except the Artillery, which was detected and located in monochrome fashion almost as fast as in the multicolored set. In general, the faster response time became obvious by considering the results related to question type 3 (Ratio). For 34 answers to 80 questions the maximum time of 10 seconds was used up for the monochrome set whereas this happened only 7 times out of 80 possible for the multicolor coded set.

The response times were analyzed under the assumption of normality, although the data set related to question type 3 (Ratio) contained many truncated data. This actually lead to an underestimation of the mean times. Since the results obtained by using both nonparametric and parametric tests revealed significantly better performance under the color coded condition, the conclusion suggests that the differences would have been even more significant if times over ten seconds had been included. Without an imposed time limit, however, the results with respect to accuracy in counting might have been different, since subjects might not had been finished counting when the shutter closed, even though inspection of the results did not indicate this occurrence. On the other hand, the time limit imposed could have encouraged the subjects (as intended) not to try to trade off time for accuracy. Results of the monochrome set for question type 3 (Ratio) clearly showed a significant decrement in response time. Inspection of the results for time related to individual symbols (Figs. 8, 9) shows different performance levels for friendly and enemy units of the same type. This might be due to different map

2. Discrimination between Friend and Enemy

Another limitation imposed upon the experiment was that the friendly and enemy symbols were not mixed. Although the symbols for enemy were double lined, the outcome might have been different for mixed units since the same colors were used for both sides. It may be that by eliminating the traditional blue-red (friend-foe) coding, enemy and friendly forces might be confused when not separated by artificial boundaries (roads or rivers).

C. UTILIZATION

The data obtained from this experiment indicated that color coding of military symbols on maps can have advantages. In general, changes of systems involve costs and organizational problems as well as requiring tradeoffs. Since the matter of interest was the application of color coding on military maps, only the most feasible utilization should be considered.

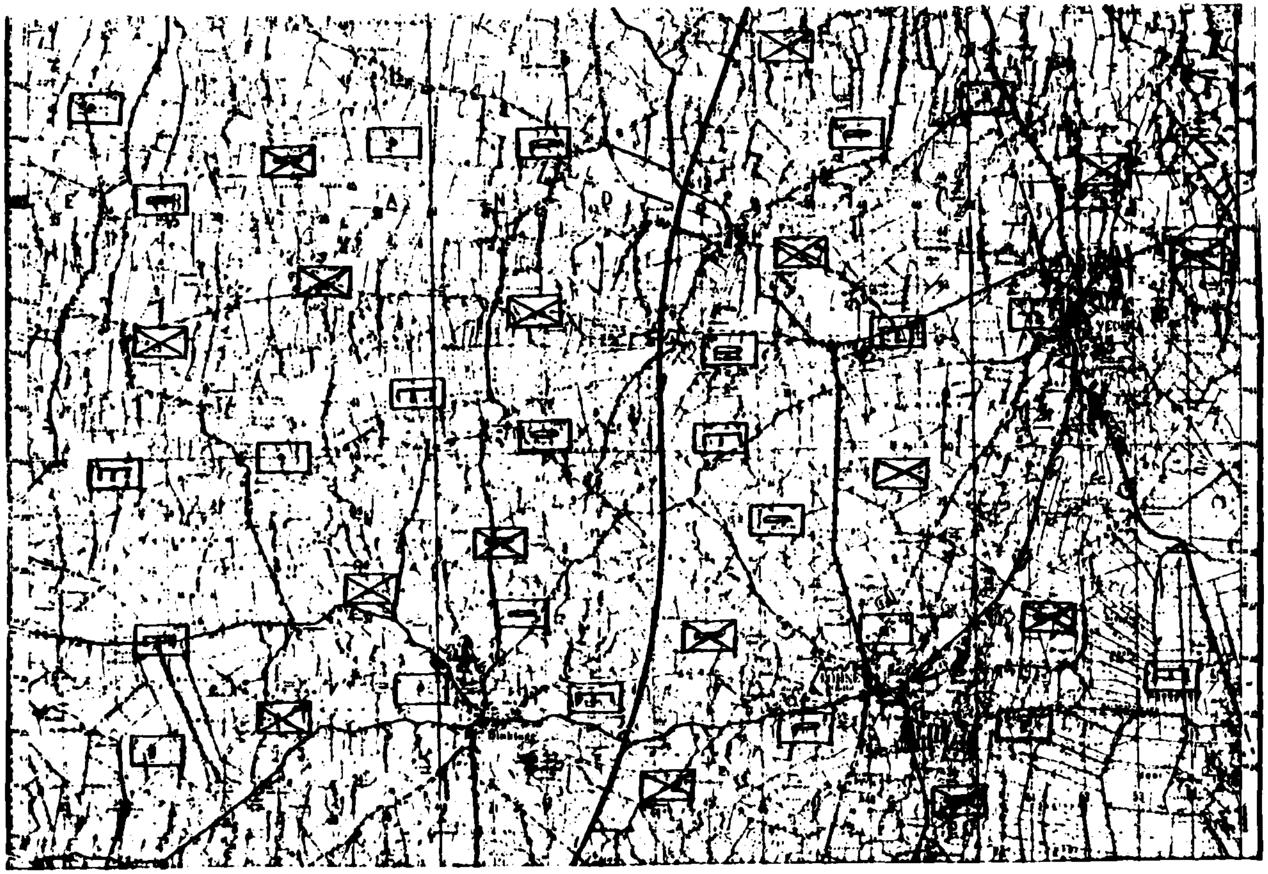
Application of color coding instead of monochrome coding does not require a costly change of symbology. Costs involved are small since color pens for any purpose are available in any military unit or agency. The utilization of the above findings are an internal organizational matter which can be decided upon by the Commanding Officer.

Since the commonly used symbols remain unchanged, there is neither penalty with respect to most individuals with color vision defects, nor extensive additional training required. In any case, the applicability of color coding will depend on the situation and the purpose a display has to serve. That is particularly true with respect to situations for which the presentation of mixed enemy and friendly forces is required.

In general, the outcome of the experiment suggested that the application of color coding to military symbols can improve human performance with respect to speed and accuracy.

APPENDIX A

SAMPLE DISPLAY



APPENDIX B

SAMPLE SET OF QUESTIONS PER SUBJECT

How	many		enemy		Artillery
	Where	is	enemy		Armor
	Where	is	own	mech.	Inf.
How	many		own		Inf.
	Ratio	of	own	Art./en.	Inf.
	Ratio	of	own	mech.	Inf./en.Art.
	Where	is	own		Artillery
	Where	is	enemy	mech.	Inf.
How	many		enemy		Inf.
How	many	own			Armor
	Where	is	enemy		Inf.
	Ratio	of	own	Inf./en.	Armor
	Where	is	own		Armor
How	many		own		Artillery
How	many		enemy	mech.	Inf.
	Ratio	of	own	Armor/en.mech.	Inf.
How	many		enemy		Armor
	Where	is	enemy		Artillery
How	many		own	mech.	Inf.
	Where	is	own		Inf.

APPENDIX C

RESPONSE TIMES BY QUESTION TYPE

RESPONSE TIMES FOR QUESTION TYPE 1 (NUMBER)
MONOCHROME

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	3.54	6.78	6.29	5.92	3.66	7.34	6.08	6.46
2	2.95	6.76	4.34	5.86	4.26	6.84	6.91	8.38
3	3.11	4.82	4.87	5.87	4.22	4.72	5.95	5.75
4	3.14	7.48	5.08	6.12	3.98	5.34	6.49	5.94
5	2.96	6.07	4.84	5.99	6.14	6.18	7.39	8.47
6	2.54	4.55	3.91	5.19	3.65	5.63	6.11	5.59
7	3.34	5.64	3.70	4.68	3.84	5.51	4.30	4.36
8	4.32	6.50	4.96	6.45	4.52	5.88	6.30	8.09
9	2.33	5.11	3.70	4.79	4.36	4.04	6.43	4.79
10	3.14	6.25	6.98	5.26	4.39	4.61	5.16	3.06
11	2.79	4.82	3.77	3.94	3.60	5.27	6.52	5.90
12	2.19	6.60	3.23	3.73	2.73	2.91	4.98	8.51
13	3.28	5.23	4.97	5.56	4.56	7.41	6.77	6.48
14	5.30	3.36	7.09	5.80	3.13	5.92	7.09	8.32
15	3.94	5.39	5.52	6.66	3.40	5.60	7.21	6.34
16	3.44	8.33	6.55	7.64	3.70	3.37	5.76	6.66
17	3.13	5.69	5.19	5.28	2.60	5.31	7.34	6.48
18	3.17	5.72	4.52	5.05	4.32	5.70	5.76	6.07
19	7.14	8.13	7.44	7.67	5.25	9.18	8.00	8.33
20	2.15	3.35	4.15	4.82	3.16	4.24	4.34	5.24

RESPONSE TIMES FOR QUESTION TYPE 1 (NUMBER)
MULTICOLOR

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	2.97	4.93	3.26	6.47	3.23	5.72	3.06	9.38
2	4.21	3.30	4.74	5.14	4.31	7.49	4.90	5.50
3	2.23	5.66	2.81	1.85	2.96	4.18	2.56	2.34
4	4.35	5.13	3.10	3.11	2.32	3.99	3.33	6.79
5	3.09	5.37	6.38	3.67	3.20	4.56	4.70	3.69
6	2.52	3.38	2.44	2.04	2.85	4.61	2.92	2.63
7	2.61	4.38	3.59	4.56	4.36	4.38	3.05	3.43
8	3.33	5.10	3.36	5.85	4.74	6.13	4.46	5.00
9	3.14	4.27	2.81	3.60	3.48	3.93	2.55	3.65
10	2.86	3.70	4.11	2.80	1.50	6.33	2.62	4.10
11	2.00	4.57	3.61	2.58	4.71	4.94	4.06	5.28
12	2.36	3.92	1.71	2.43	2.42	3.31	2.54	5.29
13	8.35	5.59	3.04	2.69	3.39	4.66	2.32	3.70
14	2.65	6.77	4.00	4.47	4.66	5.56	4.19	7.25
15	3.43	7.66	4.68	3.37	4.48	5.22	5.62	[illegible]
16	5.63	6.13	3.03	1.59	2.39	5.14	3.56	2.37
17	2.52	3.57	2.84	3.75	2.73	4.49	2.40	2.46
18	4.30	4.90	2.33	5.88	3.73	5.05	4.72	4.75
19	3.62	3.83	5.38	2.74	4.50	3.49	4.39	4.16
20	2.29	4.02	3.60	3.48	3.23	3.64	3.38	3.76

RESPONSE TIMES FOR QUESTION TYPE 2 (LOCATION)
MONOCHROME

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	6.05	6.18	9.90	8.42	7.34	8.30	7.53	9.36
2	6.78	9.24	10.00	6.25	6.44	7.19	9.98	10.00
3	8.63	8.09	9.15	8.71	9.08	9.54	9.06	9.96
4	5.18	5.46	7.12	5.55	5.23	5.70	6.08	8.99
5	7.00	6.95	9.36	9.83	5.05	9.92	10.00	9.90
6	3.46	4.25	5.12	4.54	5.59	5.13	6.92	6.85
7	3.70	5.97	5.94	3.80	4.90	4.71	5.93	5.99
8	5.39	7.56	6.41	7.53	5.19	6.84	9.38	7.91
9	7.37	6.44	6.96	6.35	5.92	7.33	6.58	10.00
10	8.09	6.49	6.08	9.91	3.97	7.46	5.42	9.91
11	6.21	7.11	6.70	7.02	6.77	7.27	8.29	7.34
12	5.46	9.26	8.46	7.15	5.82	9.07	10.00	9.76
13	6.10	7.37	7.54	7.51	6.29	7.98	9.96	9.70
14	6.01	8.05	7.32	6.73	6.47	5.51	8.14	9.46
15	8.78	8.13	10.00	10.00	8.48	6.82	10.00	10.00
16	5.34	8.64	7.36	6.47	7.83	8.20	9.99	6.55
17	6.35	6.95	7.65	10.00	7.84	7.31	10.00	9.98
18	4.76	5.50	6.14	4.53	4.72	5.04	5.77	8.49
19	8.01	10.00	9.84	8.85	10.00	9.94	10.00	9.26
20	4.47	6.74	6.57	4.46	6.08	7.83	6.34	5.39

RESPONSE TIMES FOR QUESTION TYPE 2 (LOCATION)
MULTICOLOR

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	5.22	6.54	6.76	5.07	5.80	6.69	5.05	6.84
2	7.30	6.96	7.34	7.75	7.90	9.15	6.63	8.40
3	7.77	7.43	6.31	4.97	5.66	6.44	5.35	7.68
4	5.02	6.46	4.41	4.23	4.85	5.97	6.24	5.18
5	3.30	4.87	4.38	4.17	3.06	5.10	4.55	6.32
6	4.04	3.76	3.30	2.99	2.54	4.53	3.09	4.46
7	4.92	5.26	4.69	4.42	4.44	5.21	4.53	4.36
8	5.56	6.26	8.33	5.06	6.11	8.46	5.53	5.40
9	4.15	6.75	5.55	5.69	4.51	6.89	5.46	5.01
10	5.02	4.70	5.10	3.63	3.69	3.84	3.06	5.42
11	6.86	3.52	5.17	9.94	5.67	8.42	5.34	3.07
12	8.43	7.47	3.68	3.04	5.91	7.07	6.63	2.16
13	7.74	8.73	6.38	5.22	7.40	5.22	3.16	5.32
14	4.12	3.12	7.41	4.61	4.44	7.74	5.40	9.89
15	9.99	8.61	9.24	9.31	9.94	7.09	8.00	5.86
16	6.78	4.39	3.54	2.90	3.53	5.23	3.52	3.95
17	6.36	6.35	4.14	2.97	5.11	3.24	3.76	4.11
18	5.29	5.12	4.74	5.19	4.97	7.19	5.02	6.27
19	4.09	4.55	5.11	7.57	5.13	7.17	10.00	4.23
20	6.36	7.35	5.15	7.84	4.10	5.85	6.36	9.86

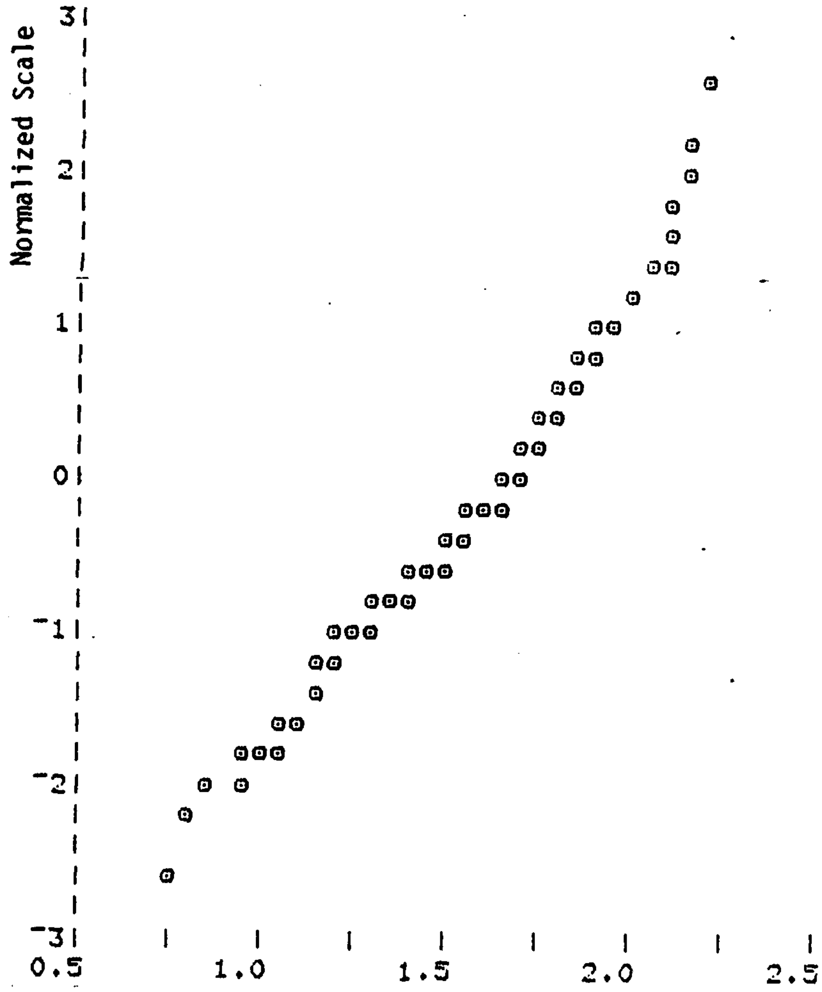
RESPONSE TIMES FOR QUESTION TYPE 3 (RATIO)

SUBJ	MONOCHROME ARTY INF	MONOCHROME ARMOR M INF	MONOCHROME INF ARMOR	MONOCHROME M INF ART	MULTICOLOR ARTY INF	MULTICOLOR ARMOR M INF	MULTICOLOR INF ARMOR	MULTICOLOR M INF ART
1	8.68	9.98	9.94	8.68	4.93	8.63	9.34	8.60
2	10.00	10.00	10.00	10.00	7.51	10.00	10.00	10.00
3	9.06	10.00	10.00	9.00	6.21	6.39	6.59	5.49
4	8.31	10.00	10.00	9.79	7.04	7.19	7.37	6.94
5	9.01	10.00	9.91	9.51	7.07	9.34	8.02	7.50
6	8.17	9.93	9.52	9.53	7.23	6.86	5.64	5.48
7	7.25	9.75	10.00	7.20	5.56	7.53	7.62	6.47
8	9.87	10.00	10.00	9.48	10.00	10.00	7.11	9.39
9	8.31	9.62	7.75	8.00	5.99	7.54	5.30	5.66
10	9.01	10.00	9.38	8.50	5.49	9.35	6.03	8.33
11	8.29	10.00	10.00	7.99	7.65	9.88	7.06	7.41
12	6.01	9.46	9.73	7.54	3.21	6.77	6.34	6.44
13	9.36	10.00	10.00	10.00	6.16	8.17	7.75	7.72
14	8.11	10.00	10.00	9.99	8.03	10.00	9.46	9.44
15	10.00	10.00	8.58	10.00	8.87	10.00	8.67	6.84
16	9.72	10.00	10.00	10.00	7.54	7.26	9.18	6.84
17	7.19	10.00	9.21	8.29	5.18	8.37	6.04	4.15
18	7.41	10.00	8.58	10.00	7.12	9.60	9.50	7.90
19	10.00	10.00	10.00	10.00	9.95	5.55	9.08	9.15
20	7.07	10.00	9.34	8.27	7.52	9.36	8.68	8.15

APPENDIX D

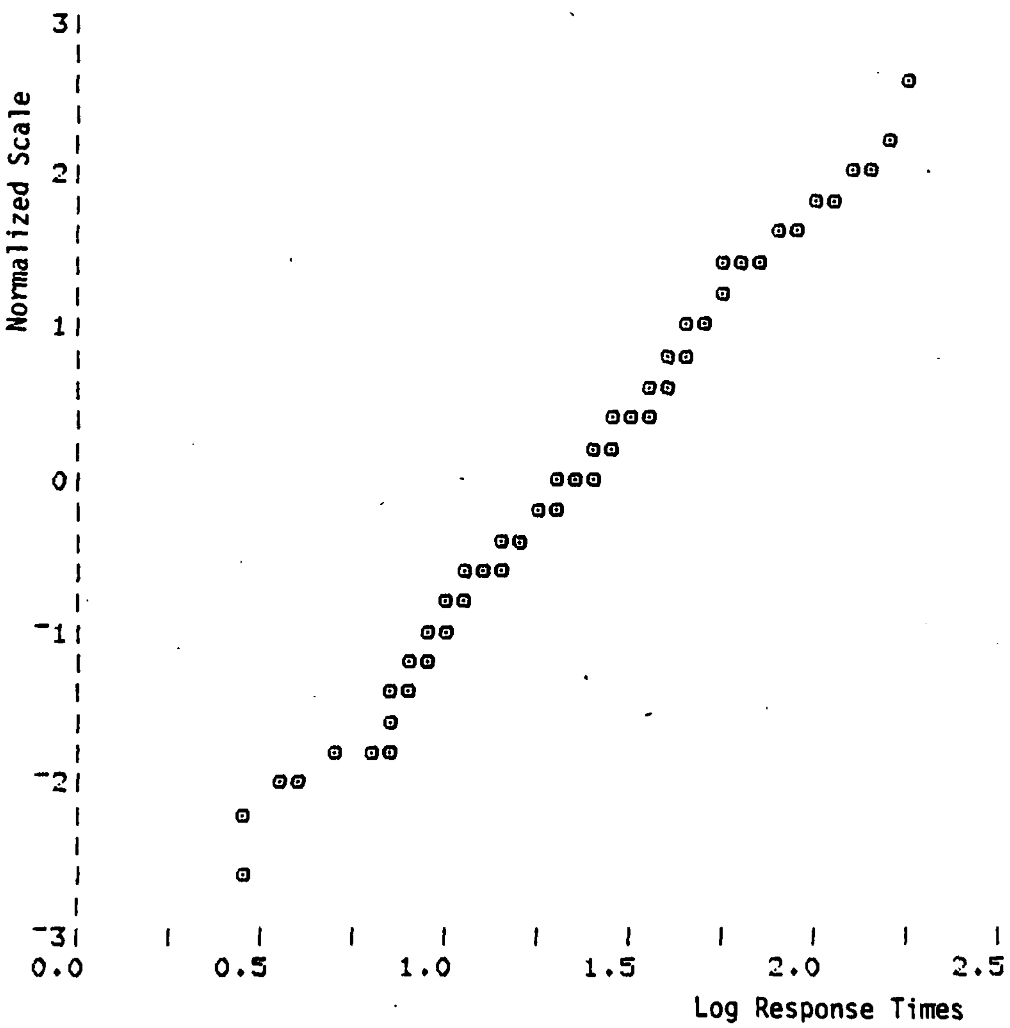
PLOT OF TRANSFORMED RESPONSE TIMES BY QUESTION TYPE (TEST FOR NORMALITY)

TRANSFORMED RESPONSE TIMES TYPE 1 (NUMBER)
MONOCHROME



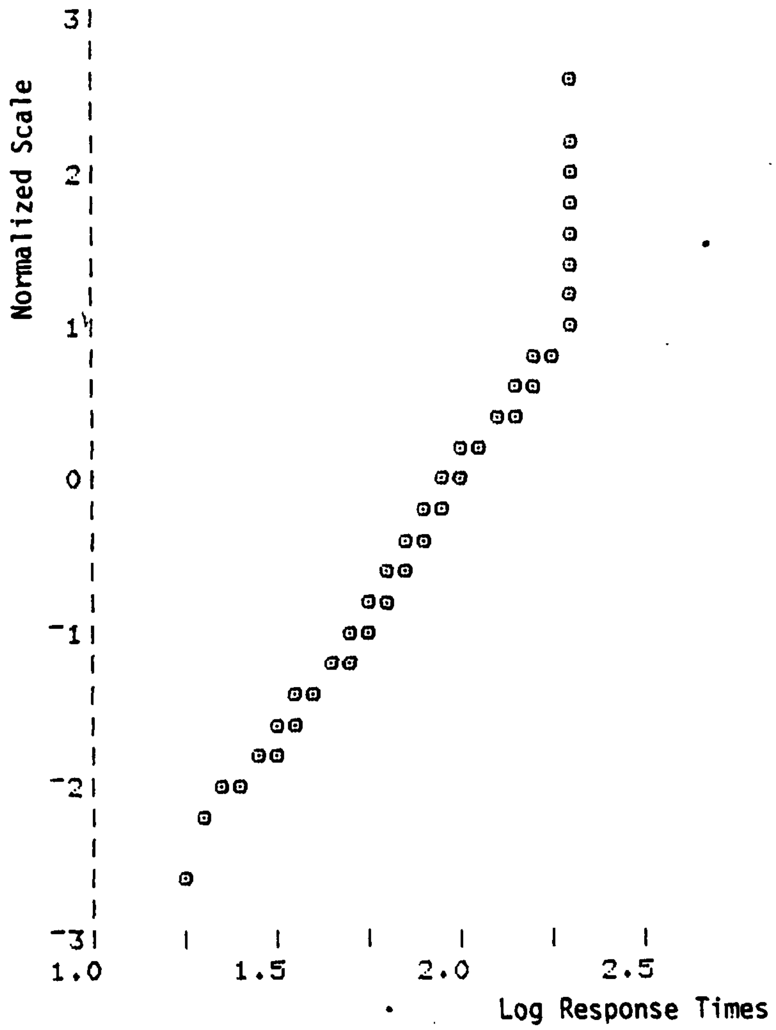
NUMBER IN EACH BIN= 22 12 9 13 14 16 21 19 20 14
EXPECTED NUMBER IN EACH BIN IS 16
CHI-SQUARE VALUE = 10.5 DF = 9
N= 160
MEAN= 1.628752859
STD DEV= 0.3176828124
VAR= 0.1009223693

TRANSFORMED RESPONSE TIMES TYPE 1 (NUMBER)
MULTICOLOR



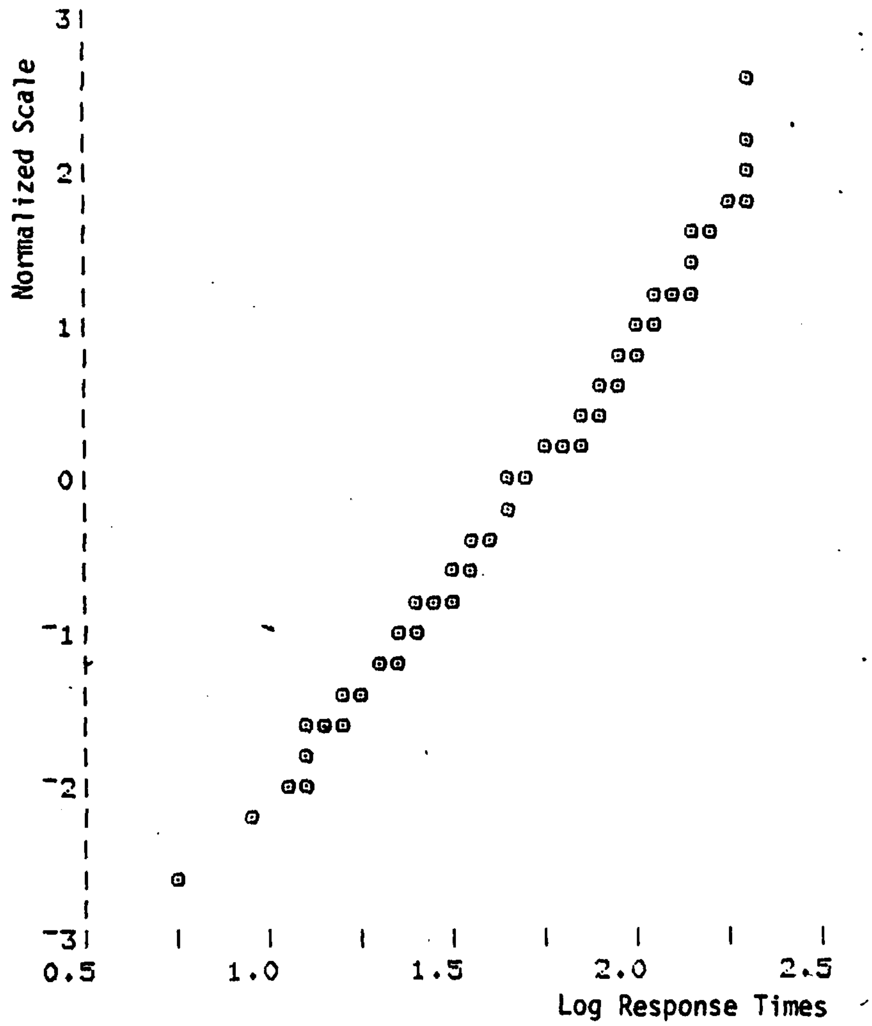
NUMBER IN EACH BIN= 16 22 12 16 15 12 16 19 18 14
EXPECTED NUMBER IN EACH BIN IS 16
CHI-SQUARE VALUE = 5.375 DF = 9
N= 160
MEAN= 1.340490128
STD DEV= 0.3480954348
VAR= 0.1211704317

TRANSFORMED RESPONSE TIMES TYPE 2 (LOCATION)
MONOCHROME



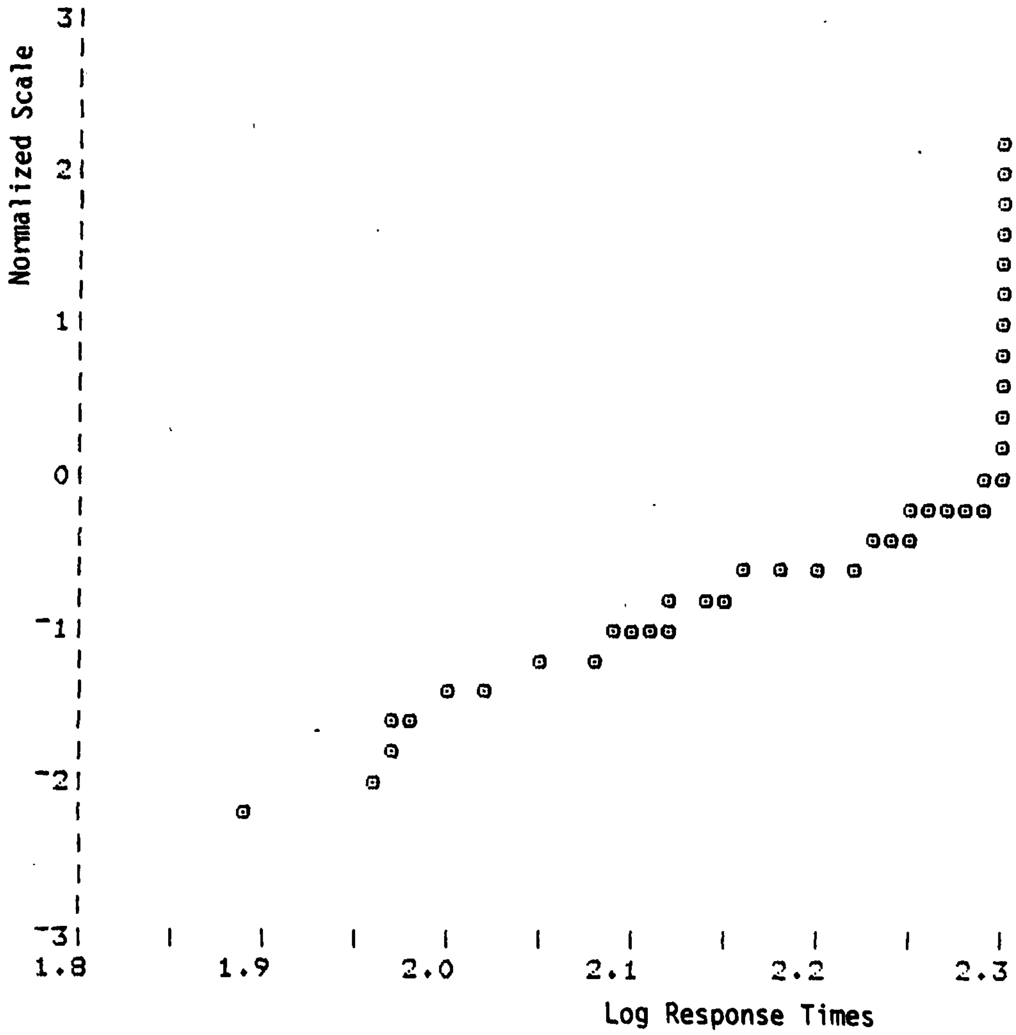
NUMBER IN EACH BIN= 19 11 18 14 16 15 14 11 23 19
EXPECTED NUMBER IN EACH BIN IS 16
CHI-SQUARE VALUE = 8.125 DF = 9
N= 160
MEAN= 1.971892477
STD DEV= 0.2534400303
VAR= 0.06423184894

TRANSFORMED RESPONSE TIMES TYPE 2 (LOCATION
MULTICOLOR



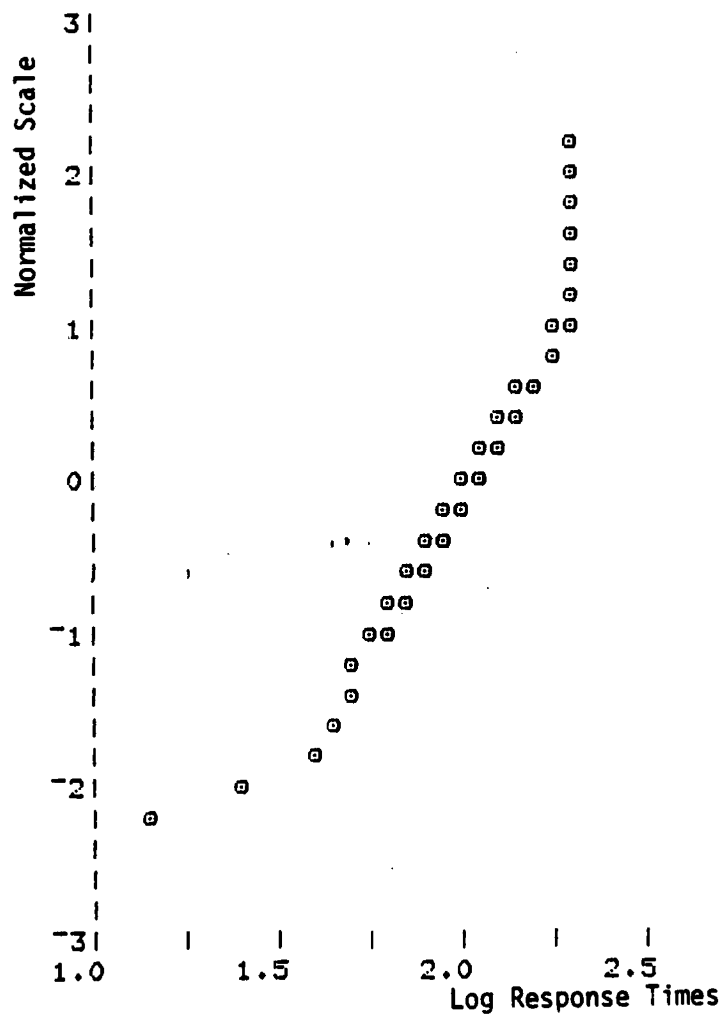
NUMBER IN EACH BIN= 17 16 14 14 22 13 12 16 19 17
EXPECTED NUMBER IN EACH BIN IS 16
CHI-SQUARE VALUE = 5 DF = 9
N= 160
MEAN= 1.706723612
STD DEV= 0.3141532853
VAR= 0.09869228665

TRANSFORMED RESPONSE TIMES TYPE 3 (RATIO)
MONOCHROME



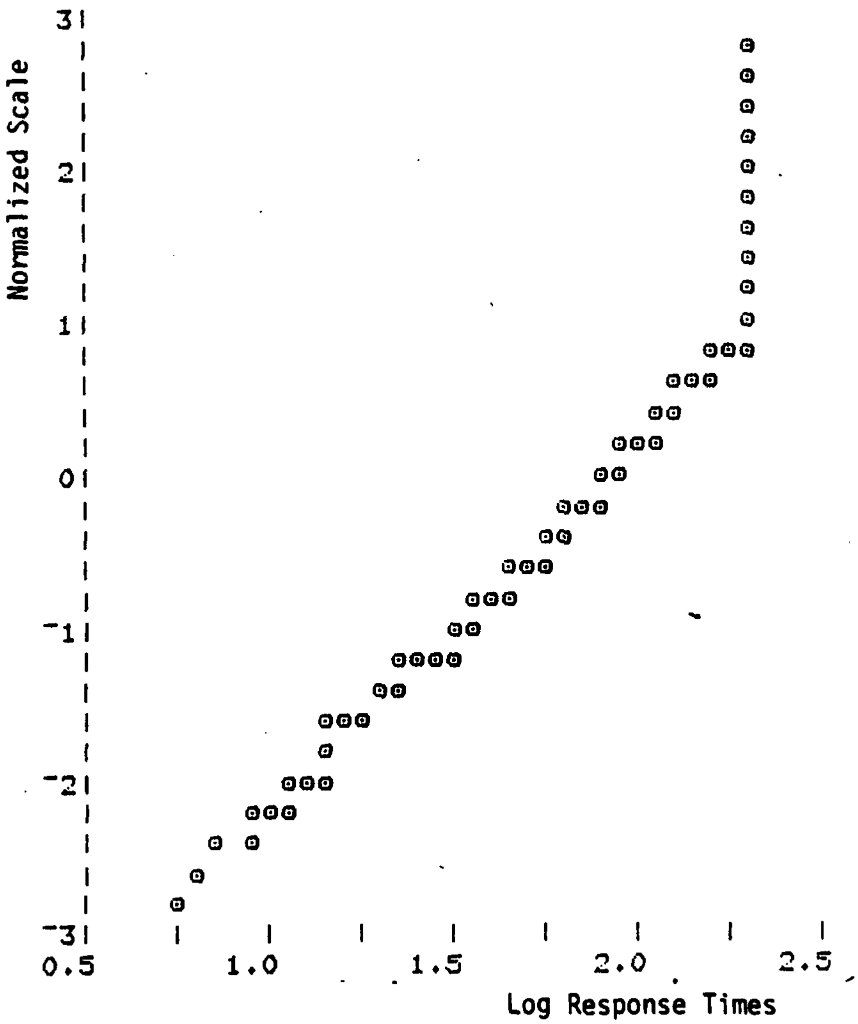
NUMBER IN EACH BIN= 10 6 5 2 1 7 5 44 0 0
EXPECTED NUMBER IN EACH BIN IS 8
CHI-SQUARE VALUE = 192 DF = 9
N= 80
MEAN= 2.229365129
STD DEV= 0.1077611659
VAR= 0.01161246887

TRANSFORMED RESPONSE TIMES TYPE 3 (RATIO)
MULTICOLOR



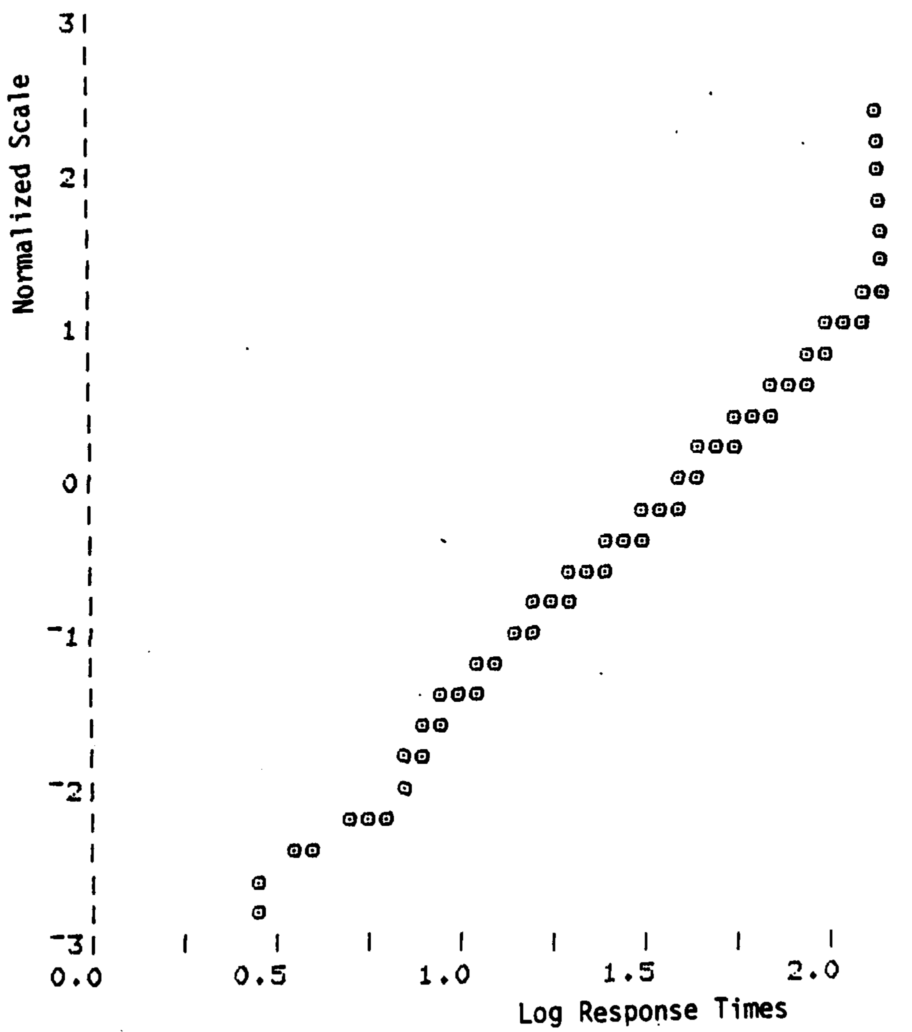
NUMBER IN EACH BIN= 10 6 5 7 7 12 6 6 21 0
EXPECTED NUMBER IN EACH BIN IS 8
CHI-SQUARE VALUE = 34.5 DF = 9
N= 80
MEAN= 2.01275668
STD DEV= 0.2280728649
VAR= 0.0520172317

COMBINED TRANSFORMED RESPONSE TIMES OF TYPES 1, 2, AND 3
MONOCHROME



NUMBER IN EACH BIN= 44 34 30 37 39 38 33 43 102 0
EXPECTED NUMBER IN EACH BIN IS 40
CHI-SQUARE VALUE = 141.7 DF = 9
N= 400
MEAN= 1.88613116
STD DEV= 0.3482050116
VAR= 0.1212467301

COMBINED TRANSFORMED RESPONSE TIMES OF TYPES 1, 2 AND 3
MULTICOLOR

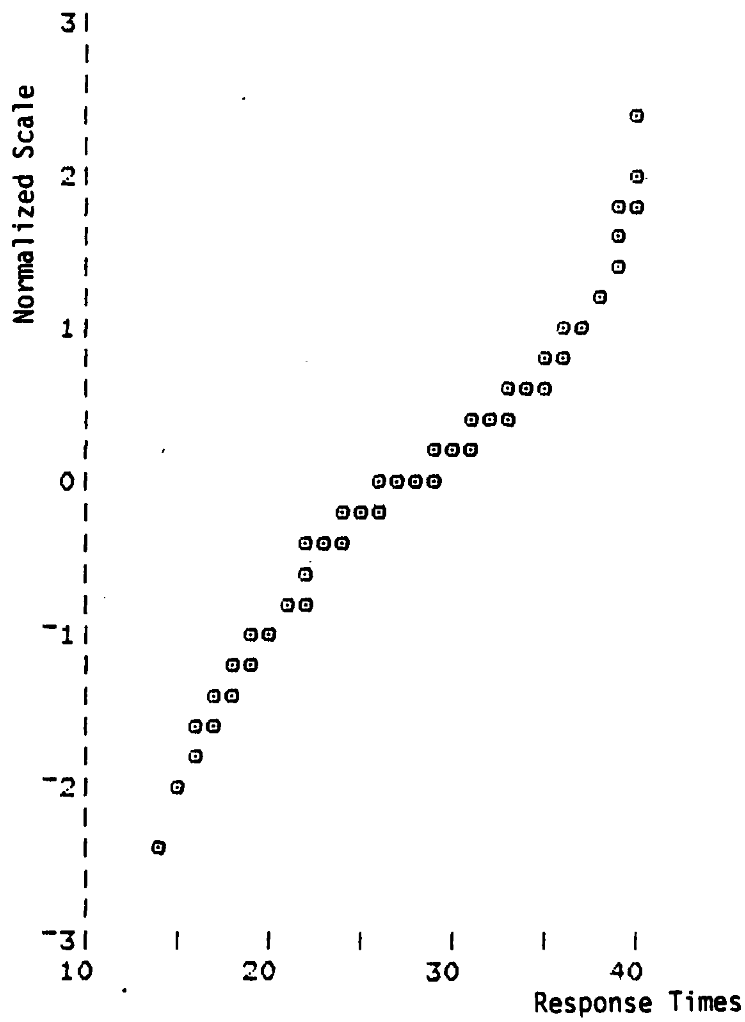


NUMBER IN EACH BIN= 47 40 29 40 35 44 29 40 54 42
EXPECTED NUMBER IN EACH BIN IS 40
CHI-SQUARE VALUE = 13.3 DF = 9
N= 400
MEAN= 1.621436832
STD DEV= 0.403961626
VAR= 0.1631849953

APPENDIX E

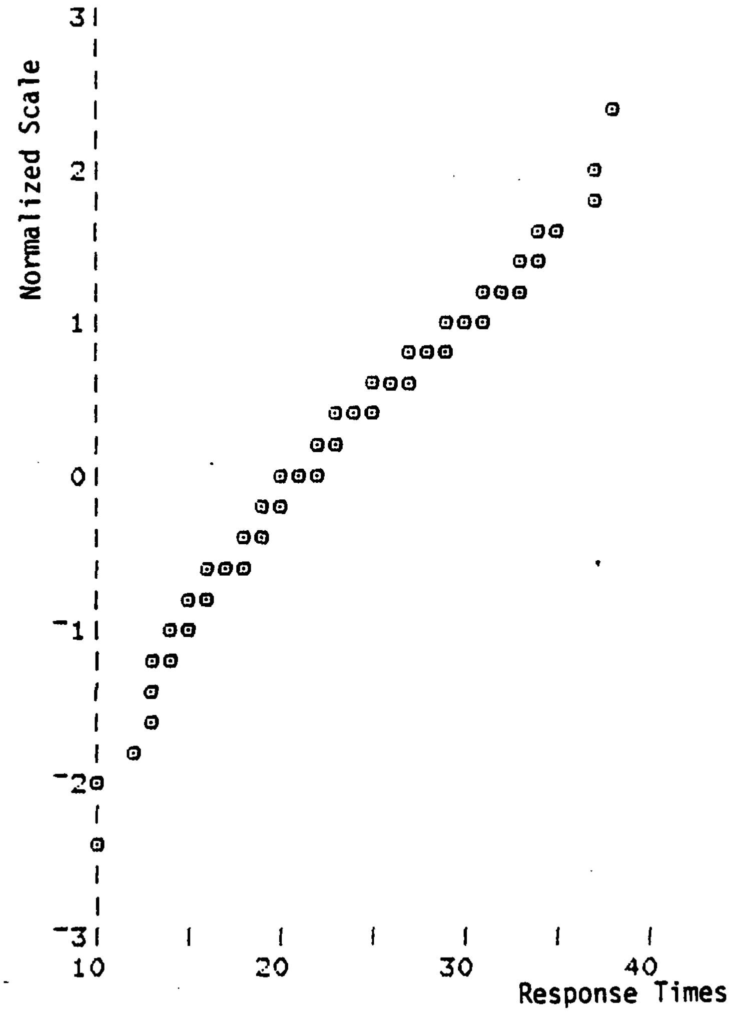
PLOT OF RESPONSE TIMES BY QUESTION TYPES SEPARATED FOR FRIEND AND ENEMY

RAW DATA USED IN ANOVA
MONOCHROME



NUMBER IN EACH BIN= 9 17 10 10 5 6 8 7 15 13
EXPECTED NUMBER IN EACH BIN IS 10
CHI-SQUARE VALUE = 13.8 DF = 9
N= 100
MEAN= 27.8794
STD DEV= 7.36215038
VAR= 54.20125822

RAW DATA USED IN ANOVA
MULTICOLOR



NUMBER IN EACH BIN= 6 17 12 10 11 8 8 7 7 14
EXPECTED NUMBER IN EACH BIN IS 10
CHI-SQUARE VALUE = 11.2 DF = 9
N= 100
MEAN= 21.8771
STD DEV= 6.945362714
VAR= 48.23806322

APPENDIX F

COMPARISON OF MEANS FOR QUESTION TYPE (FRIEND, ENEMY) UNDER MONOCHROME AND MULTICOLORED CONDITIONS

	Type 1 (Number)		Type 2 (Location)		Type 3 (Ratio)
Monochrome	397.91	457.28	567.53	617.62	747.58
Multicolor	315.69	333.85	464.82	460.03	613.32
	Friendly	Enemy	Friendly	Enemy	Friendly/Enemy

X_{11}	X_{21}	X_{31}	X_{41}	X_{51}	X_{12}	X_{22}	X_{32}	X_{42}	X_{52}		
$\frac{397.91}{20}$	$\frac{457.28}{20}$	$\frac{567.53}{20}$	$\frac{617.62}{20}$	$\frac{747.58}{20}$	$\frac{315.69}{20}$	$\frac{333.85}{20}$	$\frac{464.82}{20}$	$\frac{460.03}{20}$	$\frac{613.32}{20}$	$\bar{X}_{Diff}$	Conf. Interv.
1/5	1/5	1/5	1/5	1/5	-1/5	-1/5	-1/5	-1/5	-1/5	6.00	± 4.28
1	1	0	0	0	0	0	0	0	0	-2.97	± 4.28•
0	0	1	1	0	0	0	0	0	0	-2.50	± 4.28•
1	0	0	0	0	1	0	0	0	0	4.11	± 4.28•
0	1	0	0	0	0	1	0	0	0	6.17	± 4.28
0	0	1	0	0	0	0	1	0	0	5.14	± 4.28
0	0	0	1	0	0	0	0	1	0	7.88	± 4.28
0	0	0	0	1	0	0	0	0	1	6.71	± 4.28

$q_{.95}\ (10, 190) \approx 4.47 \quad s = \sqrt{18.35}\ ; \quad \frac{qs}{n} = \frac{4.47 \cdot 4.28}{4.472} = 4.28$

• = not significant

APPENDIX G

NUMBER OF ACCURATE RESPONSES BY QUESTION TYPE

Number		Location		Ratio	
Monochrome	Multicolor	Monochrome	Multicolor	Monochrome	Multicolor
8	7	5	7	2	3
6	7	7	8	3	3
7	8	8	8	2	4
6	7	5	8	2	4
6	7	6	6	0	3
6	8	7	7	1	3
5	7	4	8	2	4
3	8	7	8	2	3
4	8	6	7	3	3
5	8	6	8	2	3
7	7	7	7	3	3
7	8	7	7	3	3
5	7	4	8	1	4
7	8	5	6	2	1
6	8	6	7	3	4
7	8	6	7	2	2
8	8	8	8	3	4
7	8	7	7	3	4
7	8	6	7	3	4
6	7	6	7	3	4

APPENDIX H

SCORES FOR LOCATION TRANSFER

MONOCHROME

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	2.00	2.00	.33	2.00	2.00	2.67	1.33	.33
2	1.33	1.33	2.67	2.33	1.00	2.67	3.00	1.33
3	2.67	2.33	2.67	2.33	3.67	2.33	2.00	3.33
4	4.00	2.67	2.67	.67	1.33	2.33	1.67	1.00
5	2.33	.67	1.00	1.00	2.00	1.00	1.67	1.00
6	1.33	1.33	1.33	.33	.67	.33	2.67	.67
7	.67	1.67	1.00	2.00	2.67	.67	1.67	2.33
8	3.00	2.00	.33	2.00	2.33	1.33	1.33	.33
9	1.67	2.00	2.00	1.67	1.00	2.00	1.00	.00
10	2.00	1.00	2.33	2.00	2.67	2.00	1.00	2.00
11	2.33	2.33	3.33	1.67	2.67	1.00	1.00	1.67
12	1.67	2.67	4.33	3.00	2.00	2.67	1.67	2.67
13	1.67	1.00	.00	2.00	2.00	2.67	1.33	.67
14	1.67	2.00	2.67	.00	1.00	.00	1.33	3.00
15	2.33	2.00	2.33	1.00	2.67	2.00	2.33	3.00
16	2.67	.33	2.67	2.33	.67	1.67	1.33	2.33
17	3.00	1.67	4.67	1.00	3.00	1.00	2.00	2.33
18	1.33	1.00	.67	1.33	2.00	.33	1.33	.33
19	1.33	2.00	.00	2.00	1.00	2.00	4.00	.67
20	4.00	1.67	1.67	.67	2.67	1.33	3.00	2.33

SCORES FOR LOCATION TRANSFER

MULTICOLOR

SUBJ	ARTY	ARMOR	INF	M INF	ARTY	ARMOR	INF	M INF
1	2.33	3.00	2.67	2.00	3.33	2.67	3.33	2.67
2	1.00	2.00	4.67	3.00	2.33	2.67	2.33	3.00
3	3.67	2.33	4.33	2.33	3.67	2.33	2.67	3.33
4	3.33	1.33	3.67	2.67	1.33	2.33	3.67	2.00
5	3.00	3.33	2.33	1.33	1.67	1.33	1.67	3.00
6	4.00	.67	1.33	1.67	2.00	.33	3.00	2.33
7	1.67	4.00	3.00	2.67	3.33	2.00	1.00	3.00
8	.67	.67	2.00	1.00	3.00	1.33	2.67	2.33
9	1.67	1.00	3.33	2.00	2.67	2.33	1.33	2.00
10	.67	1.67	4.33	2.00	3.33	2.33	2.33	2.33
11	3.33	2.67	3.33	1.33	3.33	1.00	3.33	3.33
12	.33	.00	4.00	2.00	3.33	1.67	2.00	2.67
13	2.67	2.00	2.33	1.67	2.00	1.67	3.00	2.67
14	3.00	3.33	2.67	1.00	2.00	1.33	3.33	.33
15	.67	1.67	3.67	.00	1.33	2.00	2.33	3.00
16	1.67	2.00	2.00	1.67	2.33	.33	3.00	1.67
17	3.00	2.67	4.33	1.33	2.33	.67	1.67	3.33
18	3.00	1.33	2.33	2.33	2.33	1.67	2.33	1.33
19	1.00	2.00	2.00	.67	1.33	1.00	1.33	4.00
20	4.00	3.33	4.67	2.67	4.00	3.00	3.00	3.67

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